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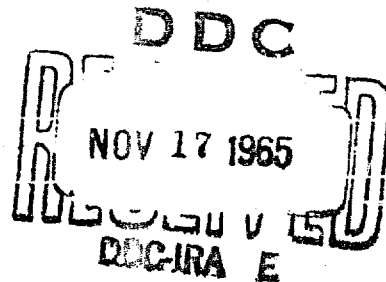
AFML-TR-65-321

MANUFACTURING METHODS FOR ELECTROPLATING SILVER,  
GOLD, AND RHODIUM ON ELECTRICAL CONNECTOR CONTACTS

Rexford E. Tweed  
Nu-Line Industries, Incorporated

TECHNICAL REPORT AFML-TR-321

October 1965



Electronics Branch  
Manufacturing Technology Division  
Air Force Materials Laboratory  
Research and Technology Division  
Air Force Systems Command  
United States Air Force  
Wright-Patterson Air Force Base, Ohio



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FOREWORD

This Final Technical Report covers all work performed under Contract AF33(657)-9752 from 15 November 1962 to 15 May 1965. The manuscript was released for publication as an RTD Technical Report on 30 September 1965.

This contract with Nu-Line Industries, Inc., 1015 South 6th Street, Minneapolis, Minnesota 55415 was initiated under Manufacturing Methods Project 7-960, "Manufacturing Methods for Electroplating Silver, Gold and Rhodium on Electrical Connector Contacts" and was accomplished under the technical direction of Mr. Robert C. Bratt of the Electronic Branch (MATE), Manufacturing Technology Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.

Mr. Rexford E. Tweed of Nu-Line Industries, Inc., was the Project Director. Others who cooperated in the engineering were Mr. Thomas Fulkerson, Mr. Ronald Plante, and Mr. Philip R. Juare. This report has been given the corporation internal number AFC-1007-D.

This project has been accomplished as a part of the Air Force Manufacturing Program with the primary objective being to develop manufacturing methods for electroplating silver, gold, rhodium, and other applicable contact plates on electrical connector contacts. Emphasis will be made on quality assurance guides and plating parameters affecting product reliability.

This contract was comprised of three phases of which six interim reports have been prepared and distributed. This report concludes and summarizes the work completed and reported in previous interim engineering progress reports.

The objective of this program is to make recommendations and contributions to the connector industry. Suggestions concerning this work or additional work will be gratefully accepted.

This report has been reviewed and is approved.

*Melvin E. Fields*

MELVIN E. FIELDS, Colonel, USAF  
Chief, Manufacturing Technology Division  
AF Materials Laboratory

## ABSTRACT

### MANUFACTURING METHODS FOR ELECTROPLATING SILVER, GOLD, AND RHODIUM ON ELECTRICAL CONNECTOR CONTACTS

Rexford E. Tweed  
et al  
Nu-Line Industries, Inc.  
(May 15, 1965)

The objective of this contract was as follows: (1) A program was directed at the problem of developing manufacturing methods for electroplating silver, gold, rhodium, and other relative contact electroplatings on electrical connector contacts. The manufacturing methods optimized under the contract emphasize quality electroplating of contacts, and minimized efforts which might normally be devoted to basic contact design and basis metal investigations. (2) The electroplating of contacts performed under this contract was directed toward improving and supplementing the quality of contacts plated under MIL-C-26636 and used in MIL-C-26500 connectors. Simultaneously, it was a specific objective of this contract to develop these contact electroplating processes and techniques in a way that the data and information obtained would serve as a guide to the improvement of contact electroplating techniques for other low frequency, low temperature, multi-pin, military connectors. (3) The work task of this contract was organized in such a manner that contact electroplating processes and techniques are upgraded and then further optimized by the dictates of "the skin effect phenomena", as applicable, so that industrial processes and controls for producing satisfactory quality contacts are firmly established. With this accomplished, military specifications for electroplating were prepared that included revisions deemed necessary as a result of this contract work. However, it is suggested that these specifications not be incorporated into the military system until still further work and updating is completed. The biggest accomplishment of this contract work is not clearly outlined or discussed in this report. That is, this program primarily laid the foundation in plating for further projects by the military. This was accomplished by bringing military people together from all branches of the service to discuss their joint problem and to what direction they should endeavor to eliminate them. Second, at the initial point of this project extreme difficulty was experienced in just where to begin. The literature and past work by other sources had not established any parameters. Therefore, this

was a testing program compiling abundant data which can be analyzed, leading to specific results and thus the foundation for future projects. This project also clearly shows where and what further work is required to upgrade the general level of reliability of electroplating and in particular the plating of connector contacts. This report signified completion of this contract work. The total program required two and one half years to complete. A discussion of all the work is contained here including a comprehensive summary.

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I.

## INTRODUCTION

A program was directed at the problems of developing manufacturing methods for electroplating silver, gold, rhodium, and other relative platings on electrical connector contacts. This plating program was primarily designed to further upgrade connector reliability and in particular the plating requirements related to the military specifications MIL-C-26500 and MIL-C-26636. The basic objective of this work was to improve and standardize plating techniques as well as to establish quality assurance through a program of process control and rigid product testing. The contract number assigned this program is AF33(657)-9752.

The stated objective of this contract was as follows:

- (1) This is a program that was being directed toward the optimization of processes and techniques for electroplating electrical connector contacts with silver, or gold and rhodium in sequence. The manufacturing methods to be optimized under this contract would emphasize quality electroplating on contacts and would minimize efforts which might normally be devoted to basic contact design and basis metal investigations.
- (2) Quality electroplating of electrical connector contacts to be performed under this contract would be directed toward improving and supplementing the quality of contacts plated under MIL-C-26636 and used in MIL-C-26500 connectors. Simultaneously, it was a specific objective of this contract to develop these contact electroplating processes and techniques in a way that the data and information obtained would serve as a guide to the improvement of contact electroplating techniques for other low frequency, low temperature multi-pin, military connectors.
- (3) The work task of this contract was organized in such a manner that contact electroplating processes and techniques would be upgraded and then further optimized by the dictates of "the skin effect phenomena", as applicable, so that industrial processes and controls for producing satisfactory quality contacts would be firmly established. With this accomplished, adequate military specifications could be written to cover electroplated contact production.

The first phase of work was completed and included a literature search, user survey, and the outline of a pilot plating line that

was used in this contract work. The literature search proved unrewarding. The lack of relevant literature was evident. Much literature was published on the topics that were considered in this investigation. However, the literature basically did not contribute to this effort due to the specialized nature of this program. There was found, however, sufficient material on plating solutions and plating techniques that is available from plating handbooks and suppliers technical material.

It was from the user survey that we acquired most of our information and were able to actually lay the ground work for the continuation of the program. We surveyed for information related to electrical connector contact plating, from which our objective was to establish the most feasible approach to quality electroplating on MIL-C-26636 electrical connector contacts.

All the organizations contacted during this survey felt that the industry could be substantially benefited by additional and improved electroplating specifications. From a study of the composite opinions and reasons that have been offered, we concluded that this could be accomplished by strong emphasis on product test standards and process controls. Therefore, it has been this contractor's approach to prepare a comprehensive set of quality assurance guides which include thorough and specific plating test standards. Process sequences are also prepared and reported for the purpose of verifying and supporting the quality assurance requirements. These standards will establish a higher level of reliability to identify and eliminate connector and contact manufacturing and operation deficiencies pertinent to plating of contacts.

The pilot line had the facilities for cleaning operations, electroplating operations, laboratory testing, and inspection evaluation. There are four significant tasks which were performed within the pilot line.

1. Investigation of plating characteristics with the objective being to develop optimum functional properties for the production of electroplated contacts at a feasible cost.
2. This investigation included the evaluation of electroplated layers in combinations of each other, considering those combinations that were found to be most appropriate from the User Survey.

3. The approach taken on all of this work was to emphasize quality assurance, process controls, and plating and cleaning sequences.
4. A basic purpose here was to stabilize the production of plated parts by any processor using the limits established from this work.

It was also this contractor's approach to continually analyze and evaluate the individual characteristics of all apparatus, chemicals, personnel, raw materials, and other factors which enter into the reliability of the end item. Our goal was to evaluate the interplay between any existing unknowns and establish adequate provisions for their control.

The nature of work covered in the second reporting period of the contract included the making of physical and electrical characteristic checks on the seven most commonly used basis metals for electrical connector contacts. The characteristic checks conducted included:

- A. Electrical Conductivity
- B. Hardness, Ductility, Crimp Evaluation
- C. Metal Cleaning
- D. Surface Finish, Grain Structure
- E. Rinsing Practices

Metal cleaning comprised approximately 50% of the effort spent during the second reporting period. This work resulted in a complete set of cleaning sequences along with data charts, test results, and guides to good cleaning. Also included, therein, was a descriptive analysis of rinsing and associated practices. The balance of this report section contains descriptive data on electrical conductivity, grain structure, surface finish, hardness, ductility and crimp evaluation.

In the third reporting period of the contract a complete set of static strip plating tests were conducted; this included plating silver, gold, rhodium, and nickel on seven contact basis materials varying the applicable parameters of plating in relation of each other. These plating parameters include current density, bath concentration, and temperature, agitation, anode area and shape, pH, bath filtration and chemical analysis. The resultant plated layers were then evaluated to determine the effect of each plating parameter relative to the characteristics of the associated layer. The test methods used to determine the quality of a plated layer



included visual inspection, surface finish, microsection, plating efficiency test, and a porosity test. The results of these tests enabled us to technically evaluate the individual effect of plating parameters relative to particular deposits. Specifically, this means that we were able to evaluate individual plating baths of the metals listed above as well as the characteristics of plating in general.

The fourth reporting period included additional static strip tests similar to those performed in the previous work segment. Emphasis was made on those areas showing poor quality assurance results in order to establish the effects and causes of poor quality plating and to determine the best method of returning a bath or plating condition back to its optimum level.

The fifth reporting period of this contract covered the initial production type plating tests which were based on the static strip plating tests completed in the prior work segment. Bath size changed from one gallon to eight gallons and parts were plated in a 2" x 4" tumbler instead of racking.

There were three important areas covered during Phase IIIb 1 through 4. They included a wearability test, further porosity investigation, and general plating tests. The wearability test basically included mating and unmating of contacts and evaluating the relative wear characteristics or ability to resist galling and abrasion. A new look was taken at porosity which included a re-evaluation of the test procedure, its reliability and value. The general plating test was a continuation of the quality assurance plating tests conducted earlier except that these tests were conducted under production of tin-nickel plating for the purposes of having a more complete and diversified evaluation of plating for electrical connector contacts.

The fifth reporting period primarily related to the continuation of plating tests begun in earlier phases and the discussion of "the skin effect phenomena." Consequently, the material reported therein was directed toward showing work completed and not toward lengthy engineering evaluations and conclusions.

The sixth reporting period was similar to the previous reporting period in the fact that it was basically a testing program where no engineering evaluations or conclusions were made at that time.

This report is the final and concluding report of this contract. All work, evaluation and conclusions are discussed and summarized in this report.

## II.

### LITERATURE SEARCH

In conducting the literature search, we surveyed university and public libraries, professional organizations, periodicals, and indexed compilations of published papers including D.D.C. It was found that most of the literature published in the field of plating is unrelated to our program, but dealt with commercial plating and its techniques as associated to the automotive, decorative, and appliance fields.

#### A. Applicable Literature Topics

Our guide to applicable literature was the article title. We selected for review papers having titles associated with (A) electroplating applicable to contacts; (B) basic electrodeposition properties and performance; and (C) connector design and functional requirements when related to plated contact finish.\* Even though we took this direct approach, many papers were still irrelevant because of the very selective field of work in this contract. The following outline shows the topics for which we found literature:

- Silver Plating
- Gold Plating
- Rhodium Plating
- Gold Alloy Plating
- Nickel Plating
- Cleaning and Preparation of Metals Prior to Electroplating
- Plating Thickness and Hardness Measurements
- Copper Oxides on the Surface of Gold Plates
- Porosity
- Galvanic Corrosion
- Dry Circuitry
- Electrical Connector Design
- Connector Designs for Low Level Circuits
- Contact Design
- The Use of Electroplated Metals in Static Contacts
- Performance of Electrical Connectors at High Altitude
- Analysis of Plating Solutions
- Electrical Deposits of Uniform Thickness
- Electrical Contact Heating
- Sliding Contact and Electrical Noise
- Wear on Electrical Properties
- Organic Deposits on Precious Metals Contacts

\* See List of Literature Reviewed on Page 10 , Table I.

Examination of Electrical Contacts by Plastic Replica Method  
Copper and Copper Alloys  
Solderability of Gold Plated Leads

B. Literature Evaluation

Initial return from the literature search proved invaluable. This directed us to probe further, being aware of the advantages of a thorough literature search. The continued search was not rewarding in relation to the amount of pertinent literature acquired. A substantial portion of our compilation came later from the User Survey. The literature accumulated is relatively complete and informative, yet due to the specialized nature of this program, only a few papers were complimentary and directive. The approximate number of printed or published papers reviewed is one hundred (100).

The following is a breakdown of the literature as it related to this program. The primary focal point for most of the current literature in this search was based on contact examination, dry circuitry, porosity measurement, galvanic corrosion, solderability on gold plated leads, and precious metal plating. In the following paragraphs, I will briefly recapitulate particular points pertinent to each of these above listed topics.

C. Contact Contamination

The literature has clearly shown that for most contact phenomena, contamination should be considered. If you are considering sulfides, oxides, dry circuitry, or solderability, contamination will be a principal factor. There has been much work done on contaminants, and one might think that in relation to this, that these papers would contribute greatly to our results. The information from these published papers does contribute somewhat, but after considering that most of these papers were written in relation to relay switches, power connectors, or other nonrelated circumstances, a new evaluation to their contribution in this program is derived. It is not our intent to imply that no paper or work has been done that contributes to this project; for there has been work done by R. Baker of Bell Laboratories, and Dr. Frant formerly of Amp, Incorporated, and by others that have contributed greatly. The total literature will be reviewed briefly, in order to eliminate the writing of a complete test on the material, and because of the relatively minor contribution the literature made to the over-all program.

The literature made the following points relating to contamination. First to be discussed is oxide and sulfide contamination. Oxide may occur on any number of contact metals including the basis metal. These oxides usually occur on the surface of the contact but can originate from the underlying or barrier plate, or from the basis metal. Sulfide also may occur on the surface of the contact and is usually attributed to the plated layers. These contaminants usually occur in conjunction with diffusion, migration, or porosity through the contact plate. In other words, there are sulfides and oxides occurring on the surface of the contact due to the presence of vulnerable sub layer metals being exposed to the atmosphere. The exposure of these metals to the atmosphere is due to porosity or intermolecular action bringing basis metal or barrier plate metal to the surface of the contact. To elaborate, an oxide or sulfide will result on the surface of a contact after a given time, whenever there are metals within the contact make-up that will oxidize or sulfide after exposure to the atmosphere. This exposure may result from diffusion, migration, porosity, or any combination thereof. The only exception to this is the proper application of plating thickness, barrier plates (such as nickel), or other controlling factors. Oxides and sulfides on contacts are not uncommon and occur readily, but they may be prevented through proper contact plate application. This topic will be further discussed under "User Survey." Contaminations, other than oxides and sulfides, that are discussed in the literature, and are also found on contacts, include organic films on rhodium plate, physical dirt resulting from atmospheric conditions or the human element, and the plating salts not adequately removed.

#### D. Dry Circuitry

Dry circuitry is also an area of considerable interest throughout the industry. This was evident in both the literature search and the User Survey. The approach most of the literature took in relation to dry circuitry has been to define a dry circuit; what it is, and what its parameters are. From the User Survey we became acquainted with many people that were quite concerned with what a dry circuit is, when do you have a dry circuit, and when don't you have a dry circuit. It has been shown that a dry circuit, under given conditions, such as temperature, and relative humidity, might become a closed circuit with the variation of one of these variables. Presently, there is considerable work being done by different organizations on dry circuitry.

## E. Porosity Measurements

Porosity measurements on contact plates, as discussed by the literature, pointed out the following facts: Porosity readily exists in contact plate, but it varies with contact plate application. The necessity for a porosity test was discussed and established by the Literature Search. Only the test itself varied from paper to paper.

## F. Galvanic Corrosion

Although there were papers dealing with galvanic corrosion, they, for the most part did not deal with the combinations of metals that we were concerned with. In many cases a paper would deal with a contact metal of interest to us, but its application usually would be in relation to another metal further down the electromotive series than we are concerned with. The other area covered by the literature on galvanic corrosion, was that of hermetically sealed contacts. The literature pointed out the possible galvanic coupling between the contact plate and the basis metal at the interface of the glass.

## G. Solderability

The literature discussed solderability on gold plated leads in relation to the problems that can occur and how they can be avoided. Soldering on gold is recognized as an accepted practice. However, many problems can arise when soldering to gold plate. The problem is one of the solder, alloying with the gold, creating a new alloy with a higher melting temperature. This new alloy solidifies rapidly causing a cold solder joint, which then results in poor adhesion and bonding properties. Recommended approach to eliminate this problem, as suggested by both the Literature Search and the User Survey, is to control the thickness of the gold plate, minimize the time cycle of the actual soldering and to take into consideration that this problem is further magnified when you have gold over nickel. In controlling the thickness of the gold plate, consider these two points:

1. Have the gold plate of sufficient thickness to allow proper alloy bonding with the solder,
2. Do not have an excess of gold causing a new alloy that is primarily gold and little solder.

When soldering to gold over nickel, precaution should be taken to not allow the soldering time cycle to become too long, so that all the gold is alloyed with the solder, and you are then attempting to bond directly to the nickel.

#### H. Precious Metal Plating

Precious metal plating is a basic part of this contract. There are a fair number of published papers dealing with this subject. Individual papers usually dealt with one particular aspect, or metal, relative to precious metal plating. Papers dealing with different contact phenomena, but related to precious metal plating, have been included in this section. Therefore, there is considerable cross reference between this and the other sections of our compilation. The following are the topics which were found in the literature relative to precious metal plating: silver, gold, and rhodium plating, microhardness, electroless plating, gold plated copper, solderability, characteristics of acid baths, galvanic corrosion, wearability, porosity, diffusion, migration, oxides, sulfides, and others.

There were three other organizations in addition to Armour Research Foundation and this contractor that have conducted a recent literature search for published material on contact plating or precious metal plating. Reference the Literature List numbers 37\* and 100\*\*, and also the E.I.A.\*\*\* subcommittee on contact plating. All three surveys had basically the same results as Armour Research Foundation and this contractor.

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- \*\* Page 21
- \*\*\* Page 53

TABLE I

PUBLISHED OR PRINTED PAPERS THAT WERE  
REVIEWED AS PART OF THE LITERATURE SEARCH

1. "Recent Developments in Gold Alloy Plating"  
by: Dr. Edward A. Parker  
Plating - June 1958
2. "Close Control Gives Reproducible Values in  
Plating Gold Selectivity"  
by: Otto F. Dingeldein  
Plating - December 1960
3. "The Prevention of Silver Tarnish"  
by: Heniz W. Dettner  
Plating - March 1965
4. "An Electron-Microscope Study of the Corrosion  
of Electroplated Nickel"  
by: Rolf Weil  
Plating - February 1961
5. "The Porosity of Electro-Deposits, Causes,  
Classification and Accessment"  
by: Arthur Kutzelnigg  
Plating - April 1961
6. "Corrosion of Dissimilar Metals"  
by: Ulick R. Evans & Vera E. Rance  
Product Engineering - December 1956
7. "Cleaning and Preparation of Metals Prior to  
Electroplating" (effect of oxide films)  
Experimental Results  
by: Dr. Henry B. Linford & David O. Feder  
April 1958
8. "The Electroplating of Tin Alloy Solderable  
Coatings on Ferrous and Non-Ferrous Base Metals"  
by: A. M. Howard & L. R. Rogers  
Plating
9. "Thickness Measurements of Platings by Means  
of Electronic Probe"  
by: Rudolph Kriegler & Berthold W. Schumacher  
Plating - April 1960

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10. "How Versatile Application Techniques for Gold Solved Aircraft and Missile Problems"  
by: William L. Aves, Jr.  
Plating - November 1959
11. "Plated Finishes: The Choice Widens"  
by: Robert T. Gore & Robert M. MacIntosh  
Product Engineering - October 28, 1957
12. "The Effect of Surface Perforation on the Tensile Strength, and Adhesion of Electro-Deposited Nickel"  
by: P. A. Brook  
Plating - November 1960
13. "Copper Oxides on the Surface of Gold Plate"  
by: M. S. Frant  
Plating - December 1961
14. "Metal Coatings for Electrical Connection"  
by: Howard B. Gibson  
Plating - July 1957
15. "Accelerated Corrosion Tests for the Performance of Plated Coatings"  
Fourth Progress Report  
by: Walter L. Pinner  
Plating - July 1957
16. "Solderability of Lead-Tin Alloy Plating"  
by: Lawrence A. Seabright  
Iron Age - December 8, 1949
17. "Measurement of Thickness of Electro-Plates by Electrolytic Stripping Method"  
by: P. B. Mathur & N. Karuppanan  
Plating - February 1961
18. "Salt Spray Testing of Tin Plated Copper"  
by: Martin S. Frant  
Plating - February 1958
19. "Electrical Connector Design"  
by: Stephen DeCoste  
Missile & Space - June 1961



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20. "New Plating Process Expands Industry Use of Gold"  
by: E. C. Rinker  
Sel-Rex Precious Metals, Inc.  
Belleville, New Jersey
21. "Connector Design Considerations for Low Level Circuits"  
by: R. J. Buchan  
Electronic Industries - July 1961
22. "Engineering in Electroplating"  
by: Century Plating Company  
White Plains, New York
23. "The Tarnish Resistance of Gold Plating over Silver"  
by: William B. Harding  
Plating - October 1960
24. "Electro-Plated Gold"  
by: Technic, Inc.  
Providence, Rhode Island
25. "Metal Coatings Improve Solder Flow on Steel and Brass"  
by: David Wallace  
Sperry Gyroscope Company
26. "Platings and Finishes"  
by: United Control Corporation  
Electro-Mechanical Design  
August 1960
27. "Connectors and Galvanic Corrosion"  
by: Dr. Martin S. Frant  
Electronic Industries - December 1961
28. "Electro-Plated Rhodium"  
by: Technic Incorporated  
Providence, Rhode Island

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29. "Bright Gold Plating"  
by: Edward C. Rinker  
Presented at 40th Annual Convention  
of American Electroplaters Society  
June 16, 1953
30. "A Compilation of Papers Published on  
Amp Research Activities in the Field  
of Plating"  
by: Amp, Incorporated
31. "The Application of Ultra-Sonic Energy  
to Metal Processing"  
by: R. J. Lanyi, D. H. Lane,  
C. A. Forbes and H. E. Ricks  
Westinghouse Electric Corporation  
Automotive Engineering Congress  
Detroit, Michigan - January 8-12, 1962
32. "Thickness and Hardness Measurements  
of Gold Deposits"  
by: Grace A. Wilson  
Sel-Rex Corporation  
Metal Finishing - June 1960
33. "Performance of Electrical Connectors  
at High Altitude"  
by: Arlie L. Coats  
Bendix Aviation Corporation
34. "Polarographic Methods for the Analysis  
of Acid Gold Alloy Plating Solutions"  
by: Arnold H. Craft and Karl Schumpelt  
Plating - March 1961
35. "Connectors"  
Electro-Mechanical Design  
July 1959
36. "Electrical Connectors for Printed Circuit  
Wiring Boards"  
by: LeRoy Gray and Albert E. Nash  
Machine Design - November 22, 1962

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37. "Technical Developments of 1961"  
by: Nathaniel Hall  
Metal Finishing - January 1962
38. "Wear in Electrical Properties"  
by: L. H. Gillespie, D. W. Saxton  
and F. M. Chapman  
Machine Design - February 18, 1960
39. "Electrical Deposits of Uniform Thickness"  
by: S. Ramachandran and S. N. Venkatakrishniah  
Metal Finishing - October 1962
40. "Dry Circuit Evaluation of Mechanical Connections"  
by: Jerome W. Kaufman, Harold R. Sutton,  
Albert V. Balchaitis & William R. Matthias  
RCA Camden, New Jersey  
Electrical Manufacturing - April 1960
41. "Copper and Copper Alloys - Their Properties  
and Design"  
by: Harold E. Barkan  
Electrical Manufacturing - April 1960
42. "Recommended Metal Combinations to Avoid Galvanic  
Corrosion"  
by: Eugene D. Veilleux  
Materials and Design Engineering - February 18, 1960
43. "Electroless Gold Plating:  
by: S. Duffield Swan and E. Lamar Gostin  
Metal Finishing - April 1961
44. "X-Ray Methods for Determination of Plate  
Thickness"  
by: Eugene P. Bertin and Rita J. Longobucco  
Metal Finishing - August 1962
45. "Rhodium Plating Thickness Measurements"  
by: Leonard Maisel  
Metal Finishing - December 1961

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- 46. "Plating With Precious Metals"  
by: A. L. Korbelak  
Sel-Rex Corporation  
American Machinists & Metal Working  
February 19, 1962
- 47. "Contact Research Expanded in Electrical  
Manufacturing Staff Report"  
Electrical Manufacturing  
August 1959
- 48. "IBM Technical Publication - Analysis of  
New Contact Design"  
By: J. Aweida  
June 6, 1958
- 49. "IBM Technical Report", "Radio Tracer, Cleaning  
and Wear Studies of Gold Plated Contacts"  
by: B. E. Blake and G. D. Fatzer  
April 21, 1961
- 50. "Electro-Deposition of Rhodium"  
by: Edward A. Parker  
Plating - July 1955
- \*51. "Trip Report on the Connector Symposium  
sponsored by: Bsd/Stl Los Angeles, California  
and visitation to Cannon Electric Company,  
Los Angeles and Santa Ana, California"  
Reported by: Rudy Schutz  
Components Engineering  
Sylvania Electronics Systems  
December 21, 1962
- \*52. "A Low Level or Dry Circuit Contact Test  
Specification and Procedure"  
by: Kenneth J. Keller  
Raytheon Company  
July 7, 1962
- \*53. "Sulfide Test for Determining Porosity of  
Gold Plating"  
RCA Corporation  
Camden, New Jersey

\* Company Internal Papers - Not Published

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- \*54. "Electrical Conductivity of NA 5-72199  
Connector Contacts in Low Level & Voltage  
Applications"  
Prepared by: Electrical Laboratory,  
North American Aviation Corporation  
Los Angeles, California - September 1961
- 55. "Gold-Plated Leads Can Cause Cold-Solder  
Joints"  
by: Charles W. Brown  
Laboratory for Electronics, Inc.  
Boston, Massachusetts  
Electronic Design - November 8, 1961
- 56. "Galvanic Corrosion"  
by: Eugene D. Veilleux  
Sanders Associates, Inc.  
Nashua, New Hampshire
- 57. "Soap Films"  
by: Mysels, Shinoda, and Frankel  
University of Minnesota  
Book No. M 541.3453-M 998
- 58. "Cathodic Protection"  
by: Lindsey M. Applegate  
University of Minnesota  
Library No. M 620.1122 - April 1952
- 59. "American Society for Testing Metals  
Symposium Report on Protecting Metals  
Against Corrosion"
- 60. "Symposium on Atmospheric Corrosion on  
Non-Ferrous Metals"  
by: ASTM #175
- 61. "How We Can Improve Dry Circuitry Operation  
and Reliability"  
by: N. C. Shaw  
Price Electric Company - Fredrick, Maryland

\*Company Internal Papers - Not Published

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- 62. "Why Does an Electrical Joint Heat"  
by: Wayne Lee Roy Henderson  
General Electric Company  
Plainville, Connecticut
  
- 63. "Sliding Precious Metal Contacts  
in Electrical Noise"  
by: E. W. Glossbrenner  
Poly Scientific Corporation  
Blacksburg, Virginia
  
- 64. "The Use of Electroplated Metals in  
Static Contacts"  
by: K. G. Compton and R. G. Baker  
Bell Telephone Laboratories, Inc.  
Murray Hill, New Jersey
  
- 65. "Materials and Process Variables and  
Their Effect on Contact Resistance"  
by: L. K. Jones, Staff Member  
Materials Laboratory  
Sandia Corporation  
Albuquerque, New Mexico
  
- 66. "Reliability Test Method for Instrument  
and Control Contacts"  
by: Merle R. Swinehart  
Cutler Hammer, Inc.  
Electrical Contact Seminar 1959
  
- 67. "Performance of Silver Contacts in  
Atmosphere Containing Silicone Vapors"  
by: L. E. Moberly  
Westinghouse Research Laboratories  
Electrical Contact Seminar 1959
  
- 68. "Organic Deposits on Precious Metal  
Contacts" (Abstract)  
by: H. W. Hermance and T. F. Egan  
Bell Telephone Laboratories  
Electrical Contact Seminar 1959

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69. "Examination of Electrical Contacts by the Plastic Replica Method (Abstract)  
by: H. W. Hermance and R. F. Egan  
Bell Telephone Laboratories  
Electrical Contact Seminar 1959
70. "Progress in ASTM Committee B-4 Work on Micro Contacts"  
by: A. L. Van Emden  
Bureau of Ships, U. S. Department of Navy  
Electrical Contact Seminar 1961
71. "Brazing, Soldering, and Welding of Electrical Contacts"  
by: K. M. Weigert  
Curtiss-Wright Corporation  
Electrical Contact Seminar 1961
72. "Identification of Contact Contamination"  
by: Earl F. Lish  
Filtors, Incorporated  
Electrical Contact Seminar 1961
73. "Investigation of Surface Contamination"  
by: Edgar Fruediger  
Texas Instruments, Inc.  
Electrical Contact Seminar 1961
74. "Friction and Wear in Sliding Contacts"  
by: Ragnar Holm  
Stackpole Carbon Company  
Electrical Contact Seminar 1961
75. "Friction Wear of Selected Metallic Contacts"  
by: I. R. Boque  
J. M. Ney Company  
Electrical Contact Seminar 1961
76. "Electrical Contact Production - Methods and Problems"  
by: S. P. Jones  
Engelhard Industries, Inc.  
Electrical Contact Seminar 1961

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77. "The Effective Area of Static Contacts"  
by: Wayne L. Henderson  
General Electric Company  
Electrical Contact Seminar 1961
78. "Film Studies of Copper Oxide at a  
Sliding Electrical Contact"  
by: W. J. Spry and P. M. Scherer  
National Carbon Company  
Electrical Contact Seminar 1961
79. "The Role of Powder Metallurgy in  
Electric Contact Manufacturing"  
by: George A. Meyer, Sr.  
Stackpole Carbon Company  
Electrical Contact Seminar 1961
80. "Duropean Contact Materials, A Foreign  
Literature Review"  
by: K. M. Weigert  
Pennsylvania State University  
Electrical Contact Seminar 1961
81. "Electroplating Engineering Handbook"  
by: A. Kenneth Graham, Editor  
Reinhold Publishing Corporation
82. "Metal Finishing Guidebook"  
Metals & Plastics Publications, Inc. (1962)  
Westwood, New Jersey
83. "The Encyclopedia of Chemistry"  
by: George L. Clark, Editor-in-Chief  
Gessner G. Hawley, Managing Editor  
Reinhold Publishing Corporation (1958)
84. "Metals Handbook"  
Properties and Selections of Metals,  
Eighth Edition; Am Society for Metals (1961)
85. "Corrosion Handbook"  
by: Herbert H. Uhlig, Ph.D, Editor  
Electrochemical Society (1948)
86. "The Merck Index of Chemicals and Drugs"  
Seventh Edition - Merck & Company, Inc.



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87. "Specifications and Test for Electro-deposited Metallic Coatings and Related Finishes" Sponsored by and Published by: American Society for Testing and Materials and American Electroplaters Society  
Third Edition - October 1961
88. "Control in Electroplating"  
by: R. R. Benham  
Robert Draper Limited  
Teddington (1959)
89. "Principles of Electroplating and Electro-forming"  
Blum and Hogaboom  
Third Edition (McGraw Hill)
90. "The Principles of Electrodeposition"  
by: Samuel Field  
Second Edition - Pitman Publishing Company
91. "Analysis of Plating Solutions"  
by: K. E. Langford  
Second Edition - Robert Draper Limited
92. "Electroplating"  
by: Mohler and Sedusky  
Chemical Publishing (1951)
93. "Production Handbook"  
by: Gordon B. Carson, Editor  
Second Edition, Ronald Publishing
94. "Standard Handbook for Electrical Engineers"  
by: A. E. Knowlton, Editor-in-Chief  
Ninth Edition (McGraw Hill)
95. "Chemistry & Physics Handbook"  
Forty-Fourth Edition 1962-1963  
Chemical Rubber Publishing Co.
96. "Cu Sol Copper Plating Process"  
Sel-Rex Corporation  
Nutley, New Jersey

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97. "WES-X314 Bright Acid Copper Process"  
Distributed by: Cowles Chemical Co.  
Cleveland, Ohio
98. "Nickel Plating from the Sulf. + Fe Bath"  
by: Richard C. Barrett  
Barrett Chemical Products Company
99. "Lectro-Nic Plating Process"  
Sel-Rex Corporation  
Newark, New Jersey  
January 1957
100. "Dry Circuit Tests and Test Equipment  
for Acceptance Testing of Relays for  
Low Level Application"  
Interim Engineering Report No. 11  
Contract AF33 (600)-33403 S/A No. 2  
by: E. R. Dubas, Project Director  
Union Switch and Signal

TABLE II  
OUTLINE OF LITERATURE

The included literature has been divided into the following categories for ease in establishing pertinent literature to a given category.

I. QUALITY CONTROL

A. #34\* #66\* #87\* #88\* #91\*

II. GENERAL OPERATION AND PROPERTIES OF PLATING BATHS

A. Gold #1\* #2\* #20\* #24\* #29\* #43\*  
 B. Silver #3\* #23\*  
 C. Rhodium #28\* #50\*  
 D. Nickel #82\* #98\* #99\*  
 E. Copper #82\* #96\* #97\*  
 F. Others #46\* #89\* #90\* #92\*

III. PLATING TECHNIQUES

A. Plating Technology and Methods

#8\* #10\* #26\* #25\* #38\* #92\* #65\* #81\*

B. Human Factors #93\*

IV. CLEANING AND PREPARATION OF BASIS METALS

A. #7\* #41\* #83\* #86\* #84\* #95\*

V. CONNECTOR DESIGN AND FUNCTIONAL REQUIREMENTS  
RELATING TO PLATED CONTACT FINISH

A. #11\* #14\* #19\* #21\* #27\* #33\* #35\*  
 #36\* #46\* #48\* #54\* #56\*

VI. PLATING FACILITIES AND PERSONNEL

A. #81\* #82\* #93\*

\*Reference literature as numbered on Table I, Pages 10 - 21.

TABLE II

VII. BASIC SCIENTIFIC PHENOMENON OF ELECTRODEPOSITS

A. Porosity #5\* #53\*

B. Galvanic Corrosion

#6\* #15\* #42\* #56\* #59\* #60\* #85\*

C. General

#4\* #16\* #18\* #22\* #31\* #36\* #47\* #49\* #51\*  
 #57\* #58\* #62\* #68\* #64\* #67\* #69\* #70\* #74\*  
 #75\* #76\* #77\* #79\* #80\* #94\* #95\*

D. Thickness Measurements

#9\* #17\* #32\* #44\* #45\* #87\*

E. Tensile Strength and Adhesion of Plates #12\*

F. Contamination on Contact Plates #40\* #72\* #73\*

Oxides #13\* #78\*

G. Plating #39\* #89\*

H. Dry Circuitry #40\* #52\* #61\*

I. Basis Metals #41\* #84\* #94\*

J. Solderability #52\* #55\* #71\*

\*Reference Literature as numbered on Table I, Pages 10-21.

### III.

#### USER SURVEY

It was from the User Survey that we obtained most of our information and direction. There were twenty-four organizations surveyed, covering an area from the east coast to the west coast. This included interviewing approximately fifty engineers and scientists, conducting thirty conferences and seventy-five telephone conversations. The information came in many forms from air frame manufacturers, connector vendors, connector users, a contact plating subcommittee, other government contracts and programs similar to ours, as well as industrial and job shop platers. The User Survey was conducted to study the connector industry that used, manufactured, or plated military connectors.

We surveyed for information related to electrical connector contact plating, from which our objective was to establish the most feasible approach to quality electroplating of silver, gold, rhodium, and other applicable contact plates for electrical connector contacts. This included the entire sequence of operations necessary for the economical electroplating of silver, gold, rhodium, and other applicable contact plates, in order to assure maximum quality of usable contacts for a given production lot.

The survey covered basic circuitry application trends for various types of low frequency (non RF types), low temperature connectors with an ambient temperature range of  $-55^{\circ}\text{C}$  to  $+250^{\circ}\text{C}$ . Factors, also surveyed, were physical structures in various sizes of associated electroplated contacts, together with the currents and ranges of frequencies conducted through each size. This information was related to each of the following seven basis metals:

Leaded Copper	98.8% Cu, 1.2% Pb
Nickel Silver	65% Cu, 18% Ni, 17% Zn
Nickel Iron	42% Ni, 58% Fe, or 52% Ni, 48% Fe
Phosphor Bronze "A"	94.31% Cu, .30% Zn, 5.08%Sn, .26%P
Chrome Copper	99% Cu, .02% Fe, .89% Cr, .03% Si, .09% Ag
Beryllium Copper #25	.97.57% Cu, .03% Zn, .001% Pb, .01% Ni, .01% Sn, .12% Fe, 1.85% Be .26% Co

G.   Leaded Brass                   59% Cu, 39% Zn, 2% Pb

This contractor maintained data charts and reports showing the value of each interrelated factor for each individual investigation of which many are included herein.

The acquired User Survey information will be reported in the following manner:

- A.   Results of Air Frame Manufacturers Survey
- B.   Results of Connector Vendor Survey
- C.   Results of Connector User Survey
- D.   Results of Other Current Contact Plating Programs
- E.   Results of Industrial and Job Shop Platers Survey

A.   Air Frame Manufacturers

User #1

- #1   The engineer stated that a definition of low level circuitry is necessary, and that there isn't one available for the industry.
- #2   Their definition of dry circuitry is anything below 30 milliamps and 30 microvolts.
- #3   User #1 has just recently become involved in low circuitry problems.
- #4   Military Specification MIL-C-26636 contacts are the only contacts they tend to use at maximum currents.
- #5   They have had problems with hermetically sealed pins. They had cases where these pins had corroded and completely fallen off.
- #6   They use the Military Specification MIL-C-26636 contacts and connector for DC to X Band radar uses. They clearly stated that they use the same connector for all applications.
- #7   They have experienced in the mating of gold to gold piece parts, a diffusion of the gold, causing the two parts to stick together.
- #8   Removal of lubrication eliminated a fretting problem in one of their mating contacts.

- #9 The engineer emphasized need for a proper method to measure plating thickness on the contact. They pointed out that the position on the contact should be called out, where the plating thickness should be measured, and also the procedure for measuring plating thickness should be called out. He also emphasized a need for a procedure to check for cracks in plating, caused by crimping.
- #10 User #1 stated that in their connector inspection department, they had connector specialists. They felt that this was necessary throughout the industry.
- #11 They experienced a silver plated contact that had whisker growth.

User #2

- #1 They use rhodium or gold over nickel and also gold over silver for its contact plates.
- #2 Their major problem in contact plating is quality control. They emphasized that they felt much work should be done in this area in order to upgrade the industry.
- #3 They have experienced a problem with excessive build-up of plate on the contact tip.
- #4 The engineer felt that there should be a nickel plate between the basis metal and the noble plate on contacts.
- #5 They do brazing and molding of wires onto the connector, particularly for high temperature contacts.
- #6 They have found that rhodium plated contacts have good properties for low level work (in the range of one microvolt).
- #7 They consider anything below one millivolt or one milli-amp as low level circuitry.
- #8 One of their big problems is that of bent pins. Basically they stated that this was due to alignment. They referenced this problem with Military Specification MIL-C-26636.

- #9 They are using many lubricated pin and socket type contacts.
- #10 Crimp cable connection is their choice, but they still use many solder type connections. In the case of small gage wire, they use both crimp and solder type connection.
- #11 They generally do not use a contact lubricant unless they feel that it is necessary.
- #12 They generally do not use a contact up to its current rating. Average current applied to a number 20 contact is one amp. For lot test purposes, however, they load a connector to fifty percent of its rating.
- #13 They know of no skin effect in their contacts.
- #14 The engineer stated that functional failures within their system are usually due to open circuits and intermittent circuits. However, they stated this was not a serious or common problem.

#### User #3

- #1 User #3 has had no major problems with silver plated contacts due to contamination. They did reference the work and papers done by Bell Laboratories and Amp, Inc., relative to oxide and sulfide contamination on gold plate. They further stated that using a thicker gold plate over silver did not eliminate migration of silver or sulfide contamination.
- #2 They felt that using rhodium plate on contacts was a poor procedure. He stated that he thought he had never seen a good rhodium plate on a contact. Reasons given for this were due to the cracking of the rhodium plate.
- #3 The engineer strongly emphasized manufacturing process control. He suggested better and stronger quality control by the vendor.
- #4 They strongly suggested that the connector vendor should have trained personnel available to the connector user, to train their personnel in the proper handling of the connector and its components.



- #5 They, at times, have had plating thickness problems with some vendors. This was solved by rejecting the parts and forcing the vendor to meet standards. However, they did not complain that there wasn't any proper control procedures for thickness of plate determinations. In other words, they didn't feel it was necessary to have regulations to determine the thickness of the plate in order to keep the vendor supplying a known thickness.
- #6 They referenced work done at Bell Laboratories and described the following example: Under strict laboratory controls, Bell Labs plated gold over nickel with no problems, but if they treated the nickel for hydrogen embrittlement before gold plate, then the gold would peel readily after plating. This statement was given in relation to their defense of gold over silver plating as opposed to gold over nickel plating.
- #7 They have been aware of sulfide contamination and have seen it in some of their contacts. However, they have considered it of no problem at this time. One case of sulfide contamination they cited was due to extended exposure to the atmosphere before assembly of the contact. In other words, shelf contamination. They stated that for their application sulfide or oxide is wiped and is no problem.
- #8 In the nickel plating of contacts, the following is a problem with User #3; solderability of the contact when you have gold over nickel plating.
- #9 User #3 has experienced nickel contamination on gold that presented a serious problem for them. Examples given were, galling and electrical conductivity.
- #10 They like to avoid capacitive circuits or connectors.
- #11 They, for the most part, discourage an energized break of a connector. Also they do not approve in using a connector as a switch.
- #12 They prefer a hooded contact, and they do not want the spring to carry the current.
- #13 They make one thousand connects and disconnects as one of their contact requirement tests.

- #14 The incidents of failure, in relation to a major connector crisis, within their organization, would occur once every three weeks for an average period.
- #15 They have no information pertinent to lubrication of contacts.
- #16 They usually do not dictate the basis metal of the contact, however, when they do, it is usually brass or leaded copper.
- #17 Voltage drop requirements in connectors for User #3 are not critical. Normal basis metals for contacts are usually acceptable by them.
- #18 Failures in connectors due to the faults of the manufacturer are as follows:
  - A. Bent contacts.
  - B. Loss of plate due to clip lead connect and disconnect.
  - C. The failure to meet tolerance of connectors.
  - D. Improper design applications for connectors.

#### User #4

- #1 Storage of contacts is a problem at User #4. Particularly silver plated contacts, after a period of time, will have a substantial silver oxide and silver sulfide contamination. They referenced here Military Specification MIL-C-5015.
- #2 They have experienced plating problems in plating of cavities, solder pots and crimp barrel areas. They can not substantially plate inside crimp barrels or within holes. Improvements suggested by them, is a bath with better throwing power, or different designs within the connector.
- #3 They use all power connectors and they stated that if there is a resistance due to contamination it is burned out.
- #4 They stated that their best results in connectors is in one piece connectors that are spring loaded.

- #5 Burrs in contacts have been enough of a problem so that they went to hooded contacts.
- #6 Poor design for application of connectors is considered a major problem for them.
- #7 Quality control by the vendor was an area that they placed greatest emphasis. Not only did they stress high quality control by the vendor, but also, that the vendor should supply trained personnel for the user. These trained personnel would go into the plants to train the user's employees in the assembling, soldering and in the proper use of the individual types of connectors.
- #8 Wear has been no problem other than those times for which they received thin plating on their contacts. This was pointed out as a problem that would have been diverted by good quality control.
- #9 They stated that they are having no major connector problems.
- #10 User #4 does not like solder pot contacts due to fire protection, and replacement difficulties. An example they gave was to replace a solder pot connector that was in a bank of hundreds of other connectors within an airplane. They would have to unsolder and solder hundreds of contacts in order to replace one faulty contact. Therefore, not only do they increase their man hours by hundreds of percent, but they increase their probability rate of other failures due to resoldering.
- #11 Size 20 and 16 contacts are used by far the most at User #4.
- #12 Their connectors usually handle from 0 to 50 amps, 3-5 amps on size 20 contacts.
- #13 They look to the day when contacts and cables will be connected automatically.
- #14 They stated that if the vendor had good rigid specifications and inspection, he would put out a good connector.

- #15 The engineer stated that uniform plating is very important for contacts. He felt that it was necessary to have a uniform plate entirely over the contact and they were not getting that at this time. He felt an emphasis should be placed on this.
- #16 There should be a program to look into something better than visual inspection of the contacts.
- #17 They also felt that there should be a program to investigate crimp contacts. They referred to the inside of the crimp, in relation to cracking of the plate and the probability of good electrical contact.

B. Connector Vendors

User #5

- #1 Gold is the only plate they recommended for contacts in high frequency applications.
- #2 The military contacts that they plate use gold over silver. The range of thickness is light gold equivalent to .000050" range, and heavy silver, equivalent to .0002" to .0003" plate.
- #3 They found gold over nickel plate for contacts satisfactory due to its high contamination resistance properties.
- #4 They have not experienced problems in soldering to gold over nickel plate as we have found in many other companies. They get very satisfactory results. Reasons given for the lack of trouble in soldering are explained as a controlled time cycle and the use of thicker gold plate.
- #5 They have experienced problems with rhodium plate due to cracking. Consequently, they avoid using rhodium.
- #6 The principle point that User #5 made at this meeting was that of quality control and upgrading the industry. They feel that a program to improve quality control and regulations to govern the producing of components for the connector is most necessary. Relative to the plating of the contacts, this would include tests and specifications, to which the plating contact would have to meet

before being supplied to the user. In breaking this point down user #5 suggested that there should be a committee that would periodically review this industry in order to keep standards and specifications updated. He felt that this would protect not only the government and other users, but the producer of the connector as well.

#7 They listed the following as problems that arise from using nickel in contact plating:

- a. The throwing power of nickel into solder pots is poor, therefore, they had problems in getting good nickel plating in these areas.
- b. They felt that the relative problems arising from contamination of a nickel basis plate as opposed to a silver basis or barrier plate is much greater. In other words, the contaminants of nickel are much harder and adhere to the surface of the contact much more readily than do the contaminants of silver. In the mating of the contacts, contaminants of silver would wipe or wear, or would even be removed, but the contaminants of nickel would tend to gall and embrittle the surface of the contact causing wear and higher electrical resistivity.
- c. They stated that in plating contacts, their usual rule of thumb would be that when plating a heavy silver basis plate, they would plate a light gold plate over the silver, and when plating a light silver basis plate, they would plate a heavy gold plate over the silver.
- d. They were not aware that current density affects the porosity of plating.
- e. User #5 placed their greatest emphasis on the need for high quality control and better inspection. However, they did state that this should have limits governed by economy and good business management. They further stated that there is a point whereby more inspection only increases cost but does not relatively increase the quality of the part.

- f. They stated that they had no feedback from their customers as to failures and problems within their contacts or connectors.
- g. They had experienced situations where a customer will call out for thicker and thicker plate on contacts and does not use good engineering evaluation. An example would be when a customer receives a bad lot of parts and concludes that there should be a thicker plate. It is their opinion that most often when a consumer has contact problems their first approach will be to apply thicker plate, feeling that this would solve their problems. They usually do not experiment, or engineer their parts further to find the proper solution.

User #6

- #1 User #6 feels that a connector vendor should not have to prove the contact plating thickness by supplying the user with some kind of calibrated information. However, they do think the vendor should guarantee the thickness of plate.
- #2 When they went to gold over nickel they experienced soldering problems. Thus they used a pure alcohol rosin flux in soldering and this seemed to eliminate their problem.
- #3 They stated that they would hesitate to have test procedures spelled out at this time for any given procedure, until more laboratory work and evaluation had been done to show that a particular test was the proven test.
- #4 Whenever they go over .0001" gold they experience a peeling problem. One case cited was in the use of .0002" gold on a contact in a missile; the gold peeled readily due to vibration.
- #5 Silver to silver contacts tend to gall and adhere to each other. This causes high insertions and withdrawal forces.
- #6 They found over a period of time, after making many tests, that on an average from all their vendors they were

receiving one half the thickness of contact plate that they had required. They considered this actually quite good.

- #7 The first combination of contact plate they went to was .000015" gold over nickel. Later they went to .00003" gold over nickel for better wear properties.
- #8 They suggest gold over basis metals or a copper flash for the crimped barrel plate.
- #9 They feel that for a real reliable contact you need .0001" gold over .0001" nickel plate.
- #10 User #6 states that the thickness of nickel plate in relation to gold over nickel contact plate should be at least .00001".
- #11 They furnish gold over basis metal to their customers, but when they need better wear properties they go to gold over nickel over basis metal.

#### User #7

- #1 User #7 feels that there is a need for development work on quality assurance as it relates to connector failures. The engineer feels that the military specifications should be improved to include quality assurance and other guide lines necessary to upgrade the industry.
- #2 They favor crimped or wire wrapped connections depending on their application, and he does not favor solder pot connections.
- #3 They run the following tests on all contacts supplied by them:
  - a. Porosity check using the nitric test.
  - b. Thickness check relative to a definite position on the contact.
  - c. They section the tested contact and make available to the user a magnified picture of the cross cut portion of the contact.

- #4 The following is a list of examples and problems within the connector that User #7 has: bent pins, pins that back off within the connector, and an occasional minor plating problem.
- #5 They prefer gold over nickel for their contacts. They consider the use of silver on contact outdated. I asked for their feeling toward gold over rhodium plate for contacts. The engineer replied that this, in his opinion was not a good application. He felt that the rhodium would crack and that the expense was too absorbent.
- #6 They feel that there should not only be a greater emphasis on quality assurance, but also on the human factor. Here they suggest that the manufacturer of connectors and contacts should have trained personnel available to be sent into the field to train the connector buyer's employees in the handling of the connector and its components. They made a strong emphasis in what might be called across the board upgrading of the connector industry.
- #7 The engineer emphasized the finish on contact plating. He felt that the plating finish was very important in contact applications. He believes that the finer the finish on the plate, the better the electrical contact between the mating pins would be.
- #8 The engineer strongly emphasized that we should not spell out plating processes when we are writing out quality assurance and test specifications.

#### C. Connector Users

##### User #8

- #1 User #8 buys contacts to the specification MIL-C-5015.
- #2 They use gold over silver on their contacts.
- #3 They do not like rhodium plate.
- #4 The engineer does think that gold, up to .000050", is the ultimate contact plate. He further stated that they have not gone to this yet.



- #5 The engineer feels that 105°C is the highest you can go with a phosphor bronze as a contact basis metal. If desired to go into a higher temperature, user should use beryllium copper as basis metal.
- #6 The engineer mentioned that in their 5015 connector they did get into high frequency circuitry, but he did not state a figure. However, they do not have high enough frequency to have skin effect.
- #7 Neoprene and a soft rubber insulation is acceptable to moisture at high altitudes. They went to a hard surface insulator due to this.
- #8 Nickel is preferred as a barrier plate when sulfur contamination is a problem.
- #9 All leads purchased by them must withstand, as one of their receiving requirements, a 270° bending.
- #10 The engineer feels that any nickel contact could not withstand crimp. He feels that the nickel plating would crack.
- #11 They have had a shelf storage problem with silver plated contacts. This problem was eliminated by proper packaging and handling of the contact.
- #12 The engineer does not like wire wrap contacts for the missile field due to high vibration in the missile. He stated that the wire wrap contact cannot compare to the crimp type contacts because the wire wrap, due to relaxation in the wire, does not physically make as strong a contact as the crimp type does, and would not withstand the high vibration of a missile.

Recommended Literature for Review by User #8:

- a. "Electrical Interconnection Reliability"  
by: Norman B. Shain  
RCA; Department Central Engineering  
Camden, New Jersey
- b. "Plated Metals as Electrical Contact Materials"  
by: Dr. Martin S. Frant  
Amp, Incorporated; Research Division  
Harrisburg, Pennsylvania

- c. "Human Factor Aspect of Connector Reliability"  
by: Joseph Denegra & Ernest E. Sadler  
Aeronautics; Division of North American Aviation, Inc.  
Anaheim, California
- d. "Reliability Program for Electrical Connectors"  
by: Mr. Bernard Lovelace  
Raytheon Company; Missiles and Space Division  
Bedford, Massachusetts

User #9

- #1 They use a standard brand name connector.
- #2 To their knowledge, they have experienced no noticeable failures or problems with their present connector, or contacts.
- #3 Some of User #9's connectors that are installed in missiles have to withstand heavy vibrations. Connector failure information is not obtainable due to the fact that the missile is destroyed upon re-entry. He did state that these were standard connectors, and that there was nothing special about them or that there were no special requirements.
- #4 They stated that contact resistance whether it is due to contamination or any environmental or other influence is of no problem to them.
- #5 A requirement of their's is that a connector must meet specifications after a three year storage period.
- #6 User #9 is looking for a connector that will withstand 1200°F, and an operational temperature of 165°F. The problem on this connector is the potting compound as explained by them.

User #10

The only relative information we obtained at this meeting was references to other places that we might visit or obtain information. These we list as follows:

- #1 Mr. Kenneth Keeler, Raytheon Company, Chapel Street, Newton, Massachusetts.

- #2 The papers presented at the November 1962 Connector Symposium; Los Angeles, California.
- #3 They suggested that we visit some of the connector manufacturers for example: Cannon; Burndy; and Amphenol.
- #4 They referenced the work done at Amp, Inc. by Dr. Martin S. Frant, and work done at Bell Labs by R. Baker, and strongly suggested we meet and talk with these people.

User #11

- #1 User #11 believes that gold over nickel plating on contacts has the draw back of poor solderability properties. The engineer emphasized using gold over silver for contact plating as opposed to gold over nickel and gave the following reasons. He feels that usually, after one or two insertions, the contacts have worn through the surface contact plate and on into the sub layer plating. Then there is the circumstance that the sub layer plate is the current carrying metal. Thus they conclude that silver, having much higher electrical conductivity over that of nickel or any other sub layer contact plate, would be much better as a sub layer plate. They also feel that the silver should be at least .0002" thick. The reasons given were that silver has better wipe ability and that silver plate tends to fill cracks and crevices in the basis metal resulting in a better surface finish. It is necessary to plate .0002" in order to get sufficient improvement of the contact surface.
- #2 They conduct a porosity test on all pins, but not on sockets that come into their organization.
- #3 Tin over nickel plate is a very good plate for contacts. It is very hard, harder than lead-tin alloy plate. They prefer tin-nickel plate on socket contacts, but do not purchase contacts with tin-nickel plate because of poor control by the vendor.
- #4 They like electroless tin plating, but see the industry going to electrolytic tin plating due to the capability of better controlling the thickness.

- #5 They consider the following as the basic causes of contact failure: sulfides; oxides; the human factor. These connector failures usually occur in test equipment.
- #6 Average rate of connector failures due to contact plating is relatively small.
- #7 User #11 made a strong emphasis that dry circuitry should not, and could not be defined. The reason given was that if you spell out the electrical characteristics of a given dry circuit and you move this circuit to a new location or change the atmospheric conditions, you might no longer have a dry circuit. They feel that the terminology "dry circuitry" or "Low level circuitry" are misleading, and are incorrectly used. In place of both of them he suggests microcircuitry.
- #8 In microcircuitry the top contact plate is the current carrying plate.
- #9 Whenever they go over .0001" gold they experience a peeling problem.

User #12

- #1 The engineer preferred rhodium plating on contacts. In reviewing plating for contacts with the engineer it was found that he had not experienced any failures or problems with rhodium plating on contacts.
- #2 The engineer, resulting from his experience, does not favor gold plating on contacts. He attributes this to poor solderability of cables to gold plated contacts. An example he cited was a contact plated with gold over silver. In this case he had solderability problems which were cold solder joints. He further stated that he had high resistance in this contact because of the poor solder connection.
- #3 They have experienced problems with a particular series of connectors supplied to them by a brand name connector manufacturer. The problem is one of loose tolerances in mated connectors, resulting in poorly mated contacts.

They have also experienced intermittent and open circuits from this. This connector vendor supplies from one-third to one-half of all their connectors.

- #4 Number of connects and disconnects that their connectors experience depends on the connector usage. If the connector is used in the field, the number of disconnects would probably be one dozen per year. However, if the connector is used in a pilot model then the disconnects would be in the order from two to three hundred times per year.
- #5 User #12 is changing to crimp type cable connections. At this time about one-half of their purchased connectors, not including RF connectors, are of the crimp type. Their RF connectors still use solder type cable connection.
- #6 The engineer expressed a liking for a brand name catalog series type connector. One of the reasons he prefers this connector is that the contact is gold plated over the copper alloy basis metal. He particularly likes this contact because of good solderability, no silver incorporated in the contact, and apparent high reliability.

This company does not presently purchase the connector, but this engineer stated that he was trying to convince management within his organization to purchase such a connector. He further stated though, that he felt that the purchasing of this connector by them was a long way off.

#### User #13

- #1 A proper connector application is a major problem at User #13. An example given was the application of a connector within their organization. He stated that they most always buy a catalog connector and adapt it to fit their requirements, as opposed to making a custom connector. This is done for financial purposes.
- #2 Bending pins is a major problem for them. Improper design mating and handling are attributed to this.
- #3 User #13 had a sulfide contamination problem when using gold over silver on the contacts. This problem was approached in two fashions:

- a. To increase the thickness of the gold plate.
  - b. To eliminate the use of silver when possible.
- #4 Storage of the contact was expressed as a major problem with User #13. This was due to silver contamination while in storage. They are considering nickel plating as a barrier plate on their contacts. The final plated contact would be gold over nickel, and they have not gone to this as yet.
  - #5 User #13 strongly suggests as a plating for contacts, heavy gold over silver, .000050" or more gold.
  - #6 The engineer stated that he had recently heard of companies using a flash of gold over rhodium plate for contact plating. He was of the impression that this was a very good combination of plate for contacts.
  - #7 The order given to connector problems by them is as follows:
    - a. Connector Application
    - b. Connector Design
    - c. Mating of Contacts.

Plating was considered a minor problem in the connector at User #13.

#### User #14

- #1 They have had times that they were concerned with contact wear. One case in particular was in the use of rhodium against rhodium in mating contacts. They stated that due to the hardness of the rhodium it caused extreme wear in the many connects and disconnects of a connector.
- #2 They suggest thickness of plate very important; .000030" to .000050" in the case of silver or gold. The reasons are wear and porosity.
- #3 They use a brand name connector that has a removable contact.
- #4 They used a brand name crimp style coax connector, but they discontinued using these connectors due to poor crimped tools supplied by vendor.

- #5 They had only one case, to the engineer's knowledge, that gold plate on the contact was too thin.
- #6 They liked the connector put out by a brand name with the contact plated with bright alloy Cu-Sn-Zn plate.
- #7 They suggest tin over nickel plate for connector contacts.

User #15

The engineer stated that he could get good plating, however, he could not continually depend upon it. He referenced the fact that platers, plating a standard part for him would not have uniform quality throughout. Another point that he made was the poor engineering, or approach that electroplaters made on different plating jobs. In expressing his experience, he felt that too often job shop platers were relying on experience when they should be relying on engineering abilities.

These were experiences and views expressed by User #15. In talking with him we found that he had many problems with electroplating mostly due to quality control. Another problem to include here would be the lack of plating know-how by them. Quite often they rely on the recommendations or experience of the electroplaters, therefore, inevitably many problems can arise.

- #1 Silver plate is the one plate that they have the most problem with.
- #2 They had a problem with silver plating on a single pin BNC connector that was silver plated. The silver plate peeled off the contact. They had to reject these connectors.
- #3 Another problem of their's is in the solder pot of the contact. They are getting thin gold plating. They are also experiencing a cold solder joint due to thin gold and an improper soldering time cycle.
- #4 They switched from silver to gold plate on a single pin connector due to peeling of the silver on the contacts. This peeling, however, did not take place until after the contact had been in use for over six months. It was suggested to them that they should switch to gold plate. This seems to have solved their problem.

- #5 The following are examples of problems they have experienced in the use of silver plate on contacts: peeling, galling, corrosion, oxides and bleeding. The peeling was due to flux contamination and long wear. The galling was attributed to long wear, six months or more of connects and disconnects of the connector. Corrosion and oxide was attributed to long bakeouts.
- #6 User #15 also experienced tarnish on gold and silver plated contacts. This investigator attributes some of this to thin plating.
- #7 We feel it necessary to point out here that many of their problems are partly attributed to their own lack of experience and familiarity with electroplating.

User #16

- #1 Solderability on gold over nickel plated contacts has not been a problem with them.
- #2 They deal with connectors that have one to one hundred pins.
- #3 They have had pin damage due to galling.
- #4 Most of their contact plating is gold over nickel, sometimes gold over bronze.
- #5 Most of their cable connections are made with solder, however, they prefer crimping. This choice is not made by them, but by the user who is buying the connectors.
- #6 They have had trouble with pre-tinned connections, due to soldering. When a connection comes into their facilities pre-tinned it is liable to have had at that time a shelf life of six months. Therefore, the pin surface has become quite contaminated, resulting in poor solderability.

User #17

- #1 The engineer feels that the ultimate in contact plating is gold over nickel. He prefers .000020" to .000030" nickel and then at least .000050" of gold on his contacts. This combination, he feels, far surpasses the other precious metal applications for contact plating.



- #2 This user would like the military specification for connectors to specify the basis metal of the contact.
- #3 Their engineer prefers crimped contacts, however, this company has not gone over to it yet. Presently they solder their leads onto the contact.
- #4 They do not like to use silver for any contact plate application.
- #5 They stated that no one would use rhodium plate as a contact plate unless they had a high temperature problem.
- #6 This user related that one of their connector vendors discontinued using rhodium over silver and went to gold over nickel. This was basically due to a contamination problem.

#### User #18

The engineer explained the plating problem that they were having and the approach they took. He showed us two contacts which were plated gold over nickel. One of the contacts is a stamped out, board mounted contact. Both contacts when being mounted have to experience a bending process. This bending is in the order of 45° bend. The problems herein are that the plating on the contacts at the point of stress, due to the bend, is cracking. This cracking is common and severe.

Originally their specifications were written to include a high degree of quality assurance. The supplier of these contacts could not meet the specifications. He complained that the specifications were too rigid and could not be met by a plater, and they, therefore, told the supplier that he would have to meet the specification or they would change suppliers. Consequently, they did change suppliers, and at this time they are still experiencing the same problem. At this point, they have been having this problem for one and one half years. In working with their second supplier, and concluding that the second supplier could not meet the standards set forth by the specifications for this contact, they found it necessary to relax nearly all of the requirements pertinent to the producing of this contact.

Now the producer can supply contacts to meet specifications. They, at this time, feel reluctant to continue this approach for they believe that it should not be necessary to lower the specifications on the contacts in order to meet the suppliers capabilities.

It was at this point in the meeting that the engineer asked us for our opinion as to the nature of the problem, and expressed the desire to establish the fact that either their specifications were too high, or that they were adequate and the plater was incompetent. Their engineer went on to say that he would like to be substantiated to the fact that these specifications are adequate, and necessary, and are not in the realm of being unapproachable by the electroplater.

D. Current Plating Programs

User #19

- #1 User #19 feels that rhodium plate is very poor for contact plating, due to oxide layers and polymer build-up on the surface of the contact. The engineer felt that this build-up was due to the presence of an insulator, and these contaminants caused high contact resistance.
- #2 This user did recommend gold flash over rhodium as the best available contact plate at this time, without considering economy. Reasons given are its good wear and non-sulfiding properties.
- #3 They do not like the use of silver in any contact plating application.
- #4 They do not feel that the use of lubricants on contacts would be generally acceptable.
- #5 They feel that gold over nickel is currently the best contact plate combination for the industry.
- #6 User #19 said that Dr. Frant previously of Amp Incorporated, and Mr. R. Baker of Bell Laboratories, are the only two working on precious metal plating.
- #7 This user strongly expressed his opinion against spelling out plating processes. This engineer felt that we should emphasize quality assurance and test procedures.

The reason for this was that this user engineer was commissioned recently by one of the nation's largest electronics companies to establish plating processes for their organizations in order to obtain uniform plating. He did this and had the following results:

Within a very short period of time, he started receiving telephone calls from engineers, within the electronic company, asking if they couldn't drop this step or that step in his process. "It doesn't seem to help much and it is very time consuming," would be the reason given.

The result was, to the very dissatisfaction of the user engineer, that within a short period of time, (about six months), the resulting plating process hardly resembled the original process, and the electronic company was again having the same trouble.

#### User #20

- #1 Silver to silver contacts tend to gall and adhere to each other. This causes high insertion and withdrawal forces.
- #2 User #20 furnished gold over basis metal to their customers, but when they needed better wear properties they went to gold over nickel over basis metal.
- #3 This user went to gold over nickel and experienced soldering problems. They went to a pure alcohol rosin flux in soldering and this seemed to eliminate their problem.
- #4 The first combination of contact plate they went to was .000015" gold over nickel. Later they went to .000030" gold over nickel for better wear properties.
- #5 They feel for a real reliable contact you need .0001" gold over .0001" nickel.
- #6 Whenever they go over .0001" gold they experience a peeling problem. One case cited was in the use of .0002" gold on a contact in a missile. The gold peeled readily due to vibration.
- #7 This user found over a period of time, after making many tests, that on an average from all their vendors they were receiving one half the thickness of contact plate that they had required. They considered this actually quite good.
- #8 They state that the thickness of nickel plate in relation to gold over nickel contact plate, should be at least .00001".

- #9 They feel that a connector vendor should not have to prove the contact plating thickness by supplying the user with some kind of calibrated information. However, they do think the vendor should guarantee the thickness of plate.
- #10 They suggest gold over basis metal, or a copper flash for the crimped barrel plate.
- #11 User #20 stated that they would hesitate to have test procedures spelled out at this time, for any given procedure until more laboratory work and evaluation had been done to show that a particular test was the proven test.

User #21

- #1 This engineer does not feel that commercial products can be relied upon for uniformity of properties.
- #2 This engineer considers basis metal surface finish to be very important. It is necessary to have a fine basis metal finish in order to have a sufficient contact metal finish.
- #3 Plating vendors are not meeting military specifications.
- #4 The state-of-the art of plating is okay, but the plating practice is below necessary requirements. Reasons given for this are personnel due to poor pay and educational conditions.
- #5 This engineer is particularly cautious about thin gold plating over nickel. This is due to wear and contact penetration through the gold into the nickel, resulting in the nickel as the current carrying metal.
- #6 Hard gold has been a problem due to cracking within the crimped barrel.
- #7 Porosity is a predominant plating problem.
- #8 This engineer feels that it would be advantageous if a plater's Receiving Department had a tougher Inspection Section.
- #9 This engineer considers rhodium a poor contact plate, due to poor solderability and dependability.

- #10 This engineer recommends heat treating of basis metals before plating.
- #11 They have no high frequency connector applications.
- #12 This engineer specifies .0001" gold over .0001" copper or .0001" gold only over basis metals that are primarily copper. He referenced missiles for this requirement.

User #22

It is deemed advantageous for all concerned to identify the following organization and to make the following suggestions. The reason is that this organization had a similar contract on contact plating with N.A.S.A. and that we have met and agreed to exchange information and conduct a working relationship. It should be noted that the only fundamental difference between the two contracts is size and approach. Armour was working on the same problems, but were taking a basic scientific approach as opposed to the practical or industrial approach that this contract takes. It is felt that these two programs will add to and compliment each other.

1. User #22 is:

Armour Research Foundation of Illinois  
Institute of Technology  
West 35th Street  
Chicago, Illinois

2. Reference:

Armour Research Foundation Project Report  
on Phase I of the N.A.S.A. Contract  
"Electrical Contact Materials for Vehicle Systems"

Number NAS8-2443; AFR Project E171  
George C. Marshall Space Flight Center  
National Aeronautics and Space Administration  
Huntsville, Alabama

- #1 The following is a quotation from the aforementioned report and is included for the purpose of giving the reader the opportunity to evaluate the results of additional literature searches.

"Special emphasis was placed on material properties and characteristics and also methods for evaluation of low level contacts. It should be noted, that a vast amount of reference material is available on the general subject of contacts, and although this material provides background and general insight, the results are not generally applicable to the particular problem of low level contacts. Only in recent years has there been concerted research activity in dry circuit contacts, with a large portion being carried out in foreign countries."

#2 The following is a quotation from the aforementioned report and is included for these two reasons:

- a. Basically, the evaluation within this paragraph is the reason for this Air Force Contract.
- b. It gives the reader the opportunity to evaluate the findings of both programs.

"Another possible cause for poor performance in gold plated contacts is the variability in the quality of gold plating from different platers. (11) Wide variations in the ability of nominally identical gold electroplates to protect an underlying silver surface were seen in specimens plated at various places in the country. Plating is still an art and not a science, and even identical baths and procedures sometimes give divergent results. The basic mechanism of electrodeposition is not clearly understood, including a variety of factors that can cause 'pinholing' roughness, non-adhesion or off-composition deposits."

(11) W. B. Harding, "The Tarnish Resistance of Gold Plating Over Silver", Plating, October 1960, pp 1141-1145.

#3 The following is a quotation from the enclosed listed report by Armour Research Foundation. This paragraph is included because it is considered relevant, and it gives the reader the opportunity to evaluate findings from both programs.

"The evaluation of plated contacts generally involves the qualitative determination of the thickness and uniformity of the plate. The thickness of plate is usually determined by photomicrograph of the cross sections or by a chemical stripping process. The measurement of porosity is somewhat more difficult although a general indication can easily be obtained by immersing the plated object in an acid which attacks only the basis metal. The measurement of weight loss provides a general measure of the degree of porosity. Diffusion of basis metal through the plate can also be a contributing factor in the formation of a corrosion film, and a general indication of its degree can also be obtained by immersion in an acid bath."

#4 Other information that was acquired from our meeting at Armour Research Foundation will not be included here in respect to its appearance in a written report by them.

#### E. Industrial and Job Shop Platers

##### Industrial Plating Supplier (Plating Baths Primarily)

This firm possessed a scientific knowledge of plating and associated chemistry, but was not directly experienced with connectors and their manufacture. Therefore, questions concerning connector applications were not asked.

This conference covered plating bath formulations, and their many variations and respective advantages. Acid versus alkaline gold solutions, high speed silver, and low stress rhodium were among the items covered. This contributor expressed a preference to acid gold for contact plating.

The various aspects of plating development, and the effects they have on the state-of-the-art were discussed. This covered plating specifications, and how they should control plated products. This engineer's opinion was that plating specifications should govern product quality, by requiring standard tests, rather than projecting a set of operational sequences.

##### Job Shop Platers

Industrial and job shop platers were surveyed in order to obtain an insight into the average capabilities of platers and to become more familiar with the needed requirements

of a standard plating establishment. We concluded after talking with platers from the west coast to the east coast that:

1. Plating processes and procedures should be included, but not required in specifications designed to upgrade the industry.
2. Conditions and facilities were generally better than is the national consensus. This was particularly true for industrial platers (large captive shops).
3. Platers generally dislike to be told how to plate, but do not resent being required to meet quality assurance requirements.

The results of the User Survey were carefully evaluated to guide us in our direction and work endeavor on this project. For example, it was clearly concluded that a specific set of plating processes could not be prepared and required by the military as a specification for their suppliers. However, plating processes must be prepared as a compliment to a rigid set of test standards. Since this project was specifically designed to produce optimum methods of electroplating, strong efforts were directed toward testing and determining the guide lines and parameters to quality and reliable plating. Less emphasis was placed on quality assurance test standards although recognizing its importance, but anticipating the requirements of future programs that would have to fill this need. Therefore, the information that resulted from this survey was used in the immediate sense relative to our testing program and plating processes and also on the long range program to better understand the end objectives and the work requirements that could only follow this project. This survey showed a tremendous need for work in all areas of plating technology and test standards of which this program might be the foundation, or stepping stone. Relative guides received from all people surveyed, when applicable, were used to efficiently direct our work.



TABLE III

USER SURVEY  
ORGANIZATIONS SURVEYED

Mr. G. G. Meese  
Mr. Melcome Bosworth  
Mr. Robert Raichlson  
Lockheed-California Company  
Burbank, California

Mr. J. A. Griffin  
Mr. Edmon Hill  
Mr. Vincent  
Electrical Control & Power Dept.  
North American Aviation Corp.  
Englewood, California

Mr. W. Olson  
Douglas Aircraft Company  
Santa Monica, California

Mr. M. R. Benson  
Mr. R. Reichel  
Mr. R. R. Willoughby  
Mr. E. E. Siefertson  
Mr. L. Boleraski  
Boeing Company  
Renton, Washington

Mr. Parker Reed,  
Material & Methods Engineer  
Mr. Henry S. Hall,  
Material & Components Engineer  
Sylvania Electronic Systems  
Waltham, Massachusetts

Mr. Norman Pool,  
Components Engineer  
Mr. Jim McGrath,  
Components Engineer  
Wayland Labs  
Raytheon Company  
Wayland, Massachusetts

Mr. Kenneth J. Keller,  
Product Planning Manager  
Industrial Components Division  
Raytheon Company  
Chapel Street  
Newton, Massachusetts

Mr. Saul Fielder, Engineer  
Avco Research & Development  
Willmington, Massachusetts

Mr. Paul Young, Engineer  
Microwave Development Labs  
Wellesley, Massachusetts

Mr. Thomas Tabor,  
Components Engineer  
Laboratory for Electronics  
Cambridge, Massachusetts

Mr. Bernard Lovelace, Manager  
Components & Specifications  
Department-Raytheon Company  
Hanscomb Air Base  
Bedford, Massachusetts

Mr. Rudy Schutz,  
Components Engineer  
Mr. Raymond Abbott,  
Components Engineer  
Sylvania Components Division  
Needham, Massachusetts

Dr. Martin S. Frant  
Assistant Director of Research  
Orion Research, Inc.  
Cambridge, Massachusetts

TABLE III

Mr. D. L. Sayrs  
Mr. Richard Zimmerman  
Mr. Malcome Brown  
Dr. John Redslob  
AMP, Incorporated  
Harrisburg, Pennsylvania

Mr. Floyd Root,  
Chief Metallurgical Engineer  
Mr. George Swanson  
Mr. Gilbert Warren  
Bendix-Scintilla Division  
Sidney, New York

Mr. Donald Grier, Buyer  
Honeywell, Inc.  
Regulator Division  
Minneapolis, Minnesota

Mr. A. R. Copp, Metallurgist  
Mr. Harold Bibus  
I.T.T. Surprenant  
Clinton, Massachusetts

Mr. Norman Shane  
Central Engineering  
R.C.A.  
Camden, New Jersey

Mr. Samuel Weiss  
(E.I.A. Subcommittee Co-Chairman  
on contact plating)  
Manager Government Contracts  
Elco Corporation  
Willow Grove, Pennsylvania

Mr. Ralph Saunders  
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Research Center  
Burroughs Corporation  
Paoli, Pennsylvania

Mr. L. Greenspan  
Engelhard Industries  
Newark, New Jersey

Mr. Joseph L. Radnik,  
Project Engineer  
Armour Research Foundation  
of Illinois  
Institute of Technology  
Chicago, Illinois

Mr. G. Mondeza  
Mr. R. Baker  
Bell Laboratories  
Murray Hill, New Jersey

#### IV.

##### PILOT PLATING LINE

This facility was designed especially for this contract to perform cleaning operations, electroplating operations, laboratory testing, and inspection evaluation. The philosophy and design concept that was followed in the outline of this plating line directed us toward establishing a producing unit with full control capabilities for experimentation, and at the same time offering conditions which would be analogous to volume production so that all data obtained would have a maximum usefulness.

##### A. Description and Functions

There were two significant tasks that were performed in this work area. The first was to determine the type and thickness of deposit layers, which would provide the optimum functional properties for production contacts at feasible costs. The second was to stabilize the production of plated parts within established limits. Current experience throughout industry demonstrated that many platers could produce quality of an acceptable level but not with adequate consistency so that the end reliability was unacceptable. It was this inconsistency and the causes for it that was the prime target of this investigation. The very things that make a processor inconsistent would be the center of attention in each of the appraisals and evaluations that went into the work task of this project. There are many unknowns that effect the properties and quality of an end product in plating. Some of these unknowns overlap in their effect causing misconceptions about what is truly a problem when processing a given part. Our goal was to evaluate the interplay between these unknowns and establish adequate provisions for their control.

##### B. Experimental Plating Line

Figure 1, Page 57 shows the plan view of the proposed plating area with the tank sequence. The total area is 500 square feet. The central area where chemical operations took place was 10 feet wide and 25 feet long. This particular design was chosen to allow construction of a closely coupled series of tanks having all their auxiliary equipment placed behind barrier walls to facilitate housekeeping and maintenance. This center operational section had a polyvinyl chloride rug laid on the floor which had a centrally located sewerage drain.

The barrier walls were faced on the front in white formica. The only objects which were on the front side of the walls were necessary controls and meters.

All other equipment including water and power distribution and ventilation was located behind the wall and fed through at required stations. This effectively reduced contamination problems. Construction of venting equipment was from stainless steel and plastics. The barrier walls extended from floor to ceiling and were sealed to prevent entry of dust or other contamination. Filtered air was piped into the work space to maintain a positive pressure. Various pieces of support equipment were located outside of this area. They were as follows: bakeout and heat test equipment; ultrasonic degreaser; deionizer; air pump; and tumbling equipment.

Comprising the complete operational sequence were various specialized tank setups. The most significant of these were the plating stations. See Figures 2, page 60 and 3, page 61 for layout and construction of the plating stations. Electrical supply equipment included: a rectifier with variable input transformer; a constant voltage regulator; DC volt and amp meters; a cathode cord reel; and provisions for connection of an amp hour meter. As shown in Figure 2, page 60 only the tank, vent hood, and electrical control apparatus was in view. All interconnections were made on the reverse side of the barrier wall. The amp meter and volt meter were removable for calibration and selection of proper range. An amp hour meter receptacle was provided to allow the insertion of an amp hour meter into the circuit. Cathode connection was made by a reeled cable prior to placing work into the solution. The flush rinse had an automatic valve so that the technician could get an immediate flow of fresh water by actuating a switch. This rinse was equipped with a large volume spray apparatus to completely flush contaminants off of in-process work. This feature was included to avoid the introduction of excess contamination in a rinse where it could be carried further into other solutions.

Two deionized rinses were included in the sequence. First a running rinse for the purpose of maintaining maximum purity of this tank which was equipped with a solu-bridge and solenoid valve. The second deionized rinse was a still bath maintained just below the boiling point. This was used in the final rinsing sequence to obtain a stained-free product. Cascade rinses were utilized to obtain maximum purity and minimum water consumption in keeping with production techniques.

The water solvent rinses were used as a final step in the processing sequence to prevent water staining and facilitate drying of parts. Other rinses and cleans were of the basic nature as listed in Table IV, Page 58.

### C. Test Laboratory

Five areas comprised the physical test laboratory:

#### 1. Microsection

Parts were cut, mounted and polished for thickness measurement in this area. Processes and equipment are per MIL-STD-151, Method 521.1 and ASTM Method A 219-54. Thickness measurements were made on a Unitron Model V-11 Metallograph. Photomicrographs provided under this contracts were also made on this metallograph. Reference thickness tests were also made on Micro-Derm Thickness Testers, Basic Unit Model MD-1B and Probe Model Number 5.

#### 2. Chemical

Solution analysis, efficiency tests, and other related chemical operations were performed in this area.

#### 3. Physical

Tensile testing, and life testing of the finished product were performed in this section.

#### 4. Electrical

Contact resistance, conductivity, and other pertinent electrical checks were performed in this section.

#### 5. Inspection

The basic inspection evaluation of products produced in the Pilot Plating Line was performed here. This included the checking of all product attributes.

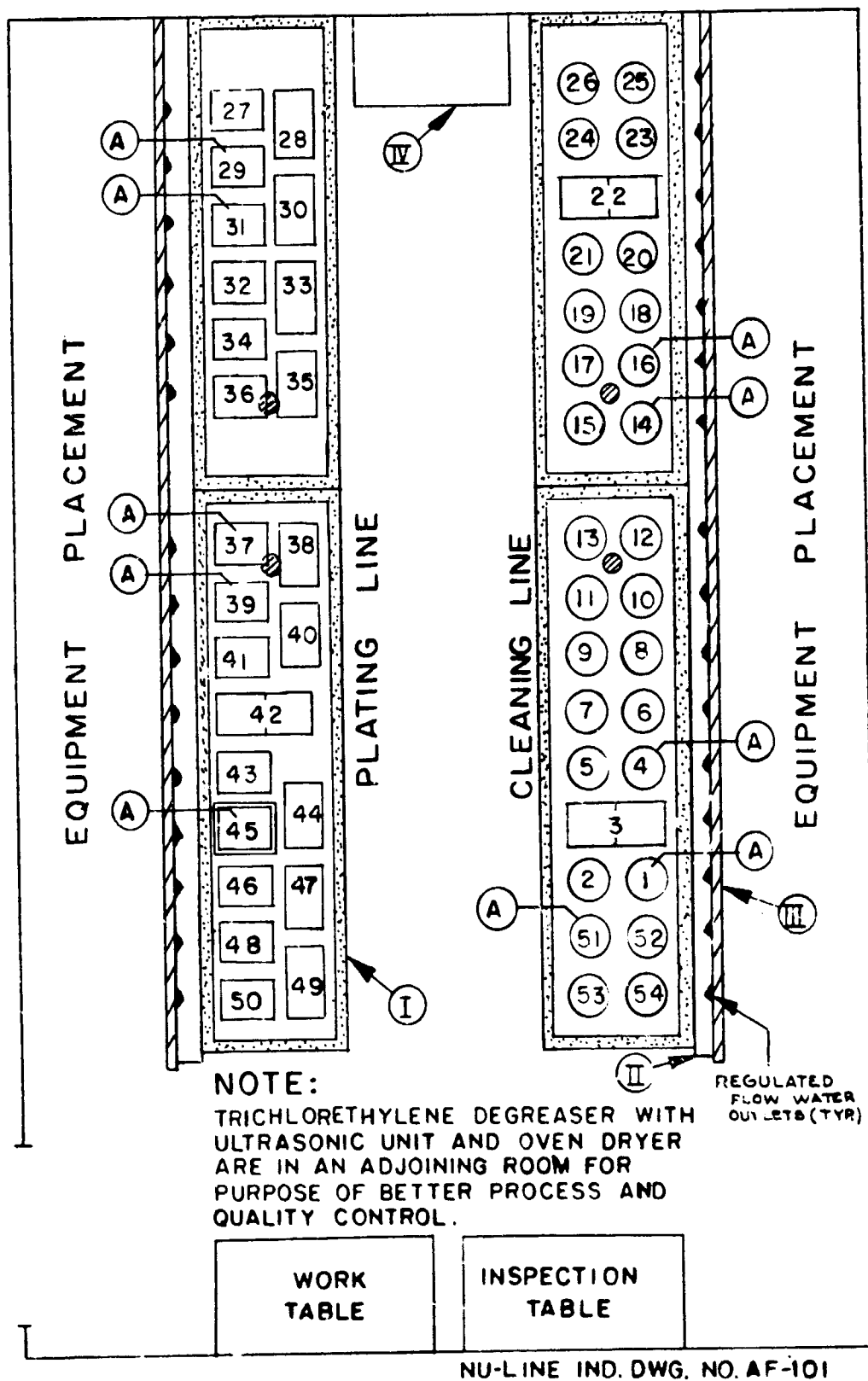


DIAGRAM II

Fig. 1 - PILOT PLATING LINE

TABLE IV  
PILOT PLATING LINE

<u>Tank Nmbr</u>	<u>Description</u>	<u>Volume</u>	<u>Material</u>
1	Detrex	5 Gals.	Polyethylene
2	Water Rinse	5 Gals.	Polyethylene
3	Cascade Rinse	10 Gals.	Polyethylene
4	12% Fluoboric	5 Gals.	Polyethylene
5	Water Rinse	5 Gals.	Polyethylene
6	Fluoboric-Nitric	5 Gals.	Polyethylene
7	Water Rinse	5 Gals.	Polyethylene
8	Ammonium Persulfate	5 Gals.	Polyethylene
9	Water Rinse	5 Gals.	Polyethylene
10	Acid Bright Dip	5 Gals.	Polyethylene
11	Water Rinse	5 Gals.	Polyethylene
12	120°F Hot Rinse	5 Gals.	Polyethylene
13	Water Rinse	5 Gals.	Polyethylene
14	12% Fluoboric	5 Gals.	Polyethylene
15	Water Rinse	5 Gals.	Polyethylene
16	Sulfuric	5 Gals.	Polyethylene
17	Water Rinse	5 Gals.	Polyethylene
18	Ferric Sulfate	5 Gals.	Polyethylene
19	Water Rinse	5 Gals.	Polyethylene
20	16% Hydrochloric	5 Gals.	Polyethylene
21	Water Rinse	5 Gals.	Polyethylene
22	Cascade Rinse	10 Gals.	Polyethylene
23	Cyanide	5 Gals.	Polyethylene
24	Extra	5 Gals.	Polyethylene
25	Extra	5 Gals.	Polyethylene
26	Deionized Rinse	5 Gals.	Polyethylene
27	Tin-Nickel (Water Jacketed)	10 Gals.	Polyethylene Nickel Anodes
28	Water Rinse	10 Gals.	Polyethylene
29	Copper Strike	10 Gals.	Polyethylene Lined Steel Tank - Copper Anodes
30	Water Rinse	10 Gals.	Polyethylene
31	Nickel Plate	10 Gals.	Polyethylene Lined Steel Tank - Nickel Anodes
32	Nickel Strike	10 Gals.	Polyethylene Stainless Steel Anodes
33	Water Rinse	10 Gals.	Polyethylene
34	Silver Strike	10 Gals.	Polyethylene Stainless Steel Anodes

TABLE IV

<u>Tank Nmbr</u>	<u>Description</u>	<u>Volume</u>	<u>Material</u>
35	Water Rinse	10 Gals.	Polyethylene
36	Silver Plate	10 Gals.	Polyethylene Silver Anodes
37	Gold Strike	10 Gals.	Stainless Steel Tank Stainless Anodes
38	Water Rinse	10 Gals.	Polyethylene
39	Gold Plate	10 Gals.	Polyethylene Stainless Steel Anodes
40	Water Rinse	10 Gals.	Polyethylene
41	Gold Plate (Xrosene)	10 Gals.	Polyethylene Stainless Steel Anodes
42	Cascade Rinse	10 Gals.	Polyethylene
43	Gold Drag (Rinse)	10 Gals.	Polyethylene
44	Water Rinse	10 Gals.	Polyethylene
45	Gold Plate 24K (Water Jacketed)	10 Gals.	Polyethylene Platinum Anodes
46	Gold Plate	10 Gals.	Polyethylene
47	Water Rinse	10 Gals.	Polyethylene
48	Gold Plate	10 Gals.	Polyethylene
49	Water Rinse	10 Gals.	Polyethylene
50	Acetic Acid Dip	10 Gals.	Polyethylene
51	Hot Deionized Rinse	5 Gals.	Stainless Steel Tank
52	Alcohol (Isopropyl)	5 Gals.	Polyethylene
53	Alcohol (Isopropyl)	5 Gals.	Polyethylene
54	Alcohol (Isopropyl)	5 Gals.	Polyethylene

A: Heaters (1000 Watt)

- I: Sink Type Tank Tables (4 Places)
- II: Slotted Vents (2 Places)
- III: White Formica Front Walls (2 Places)
- IV: Process Table and Static Strip Test Area



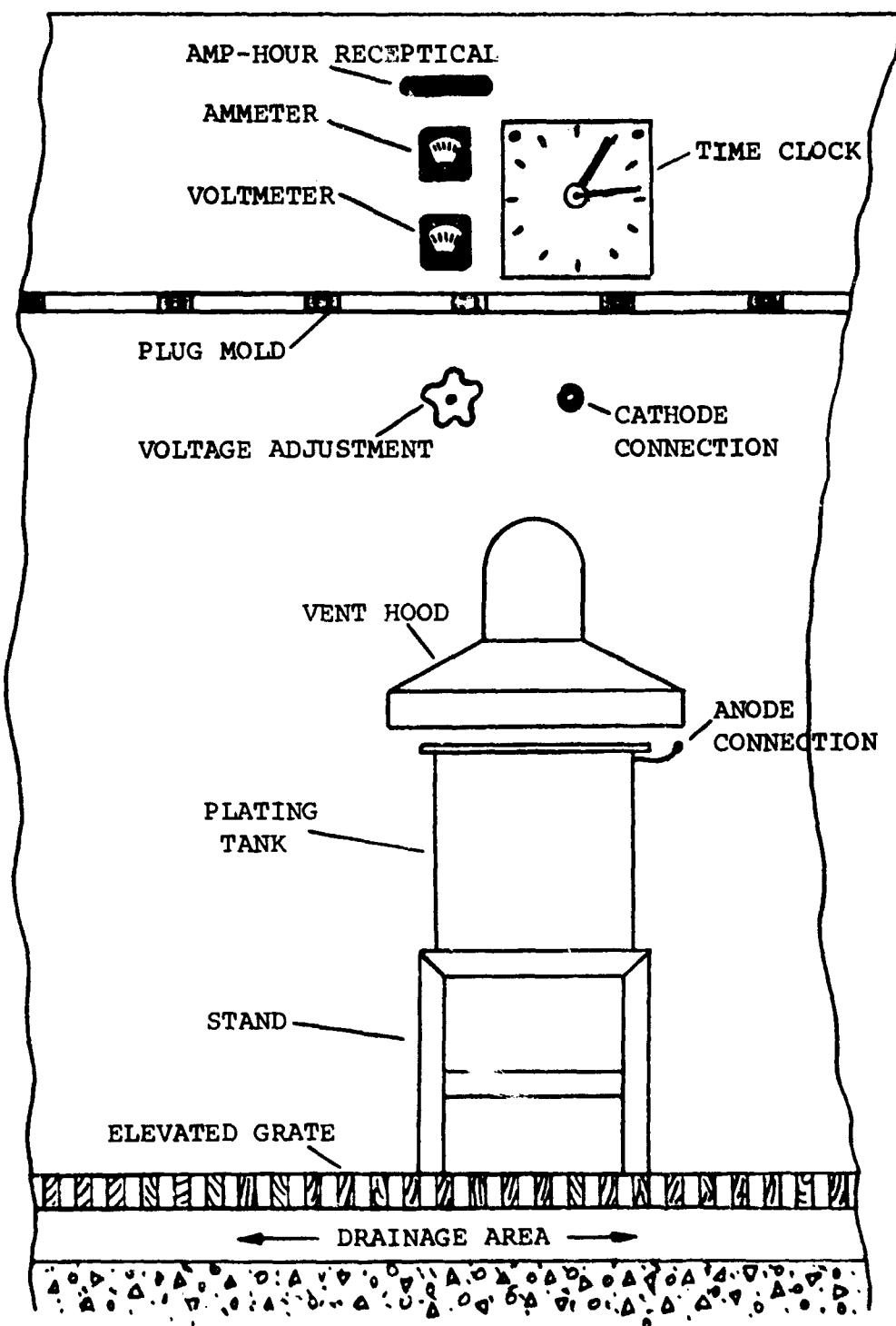


FIGURE 2 FRONT VIEW OF TYPICAL PLATING STATION  
WITH WHITE FORMICA WALL.

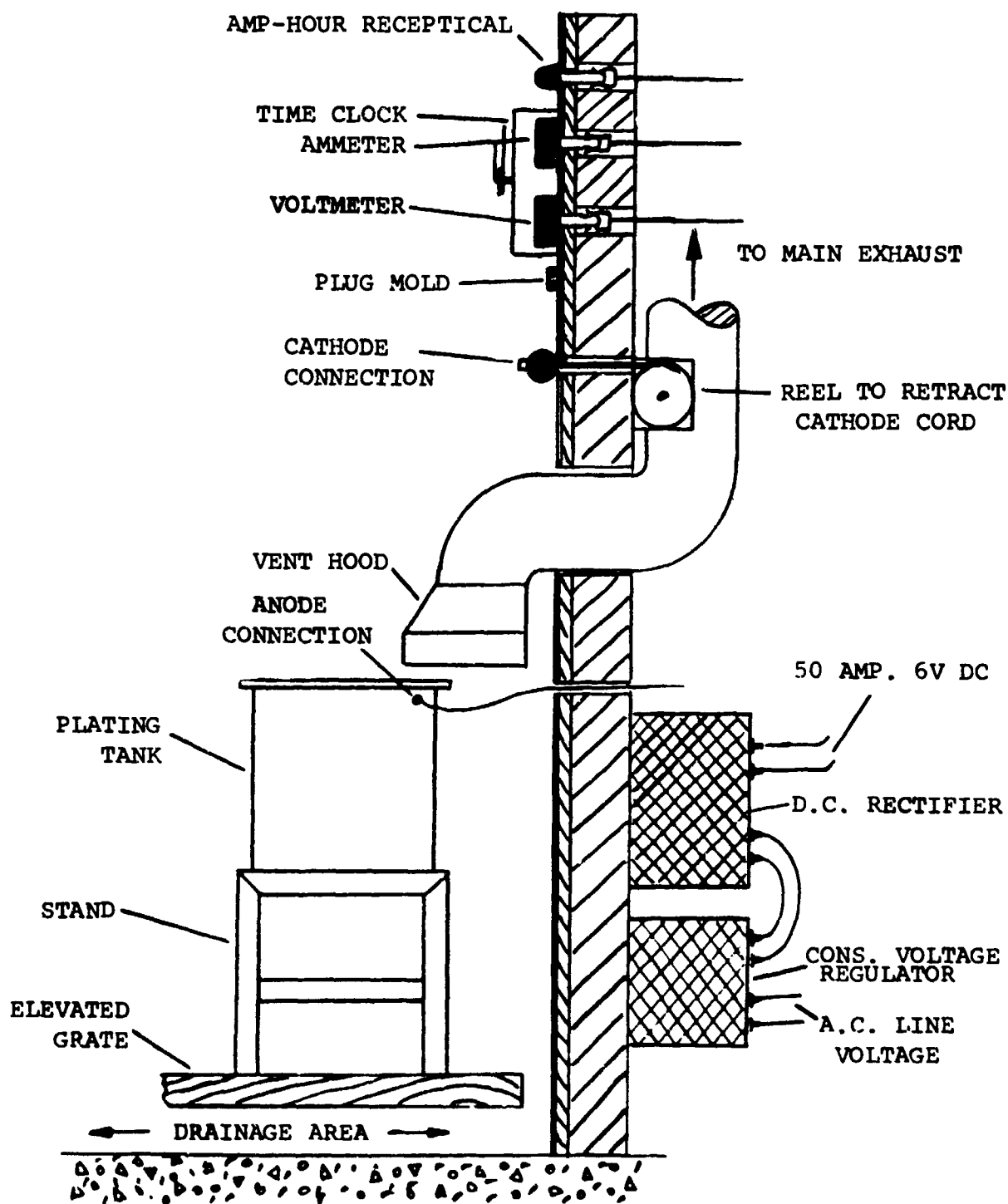


FIGURE 3 SIDE VIEW OF TYPICAL PLATING STATION SHOWING HOW ALL AUXILIARY EQUIPMENT IS LOCATED IN BACK OF THE WHITE FORMICA-FACED WALL.

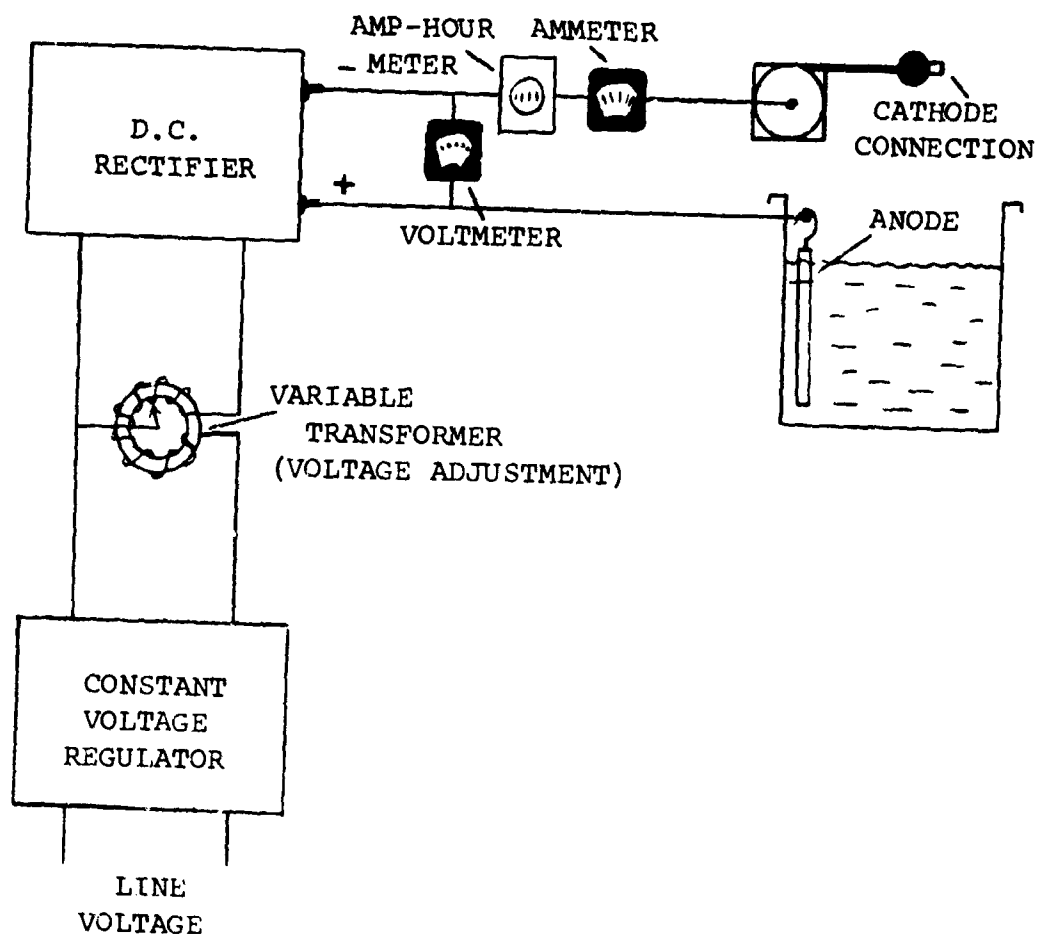
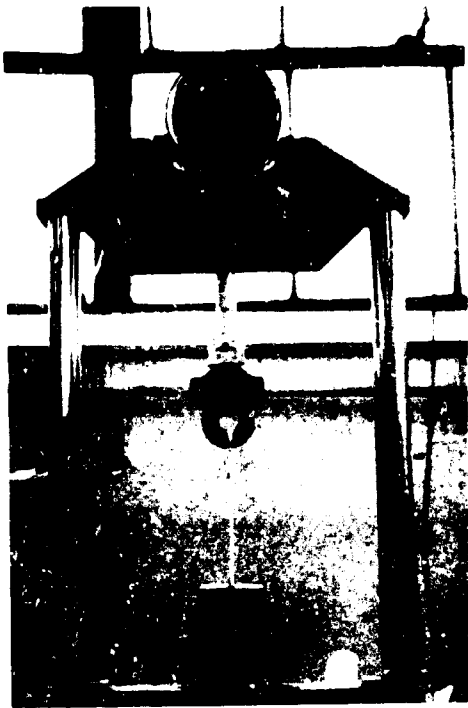
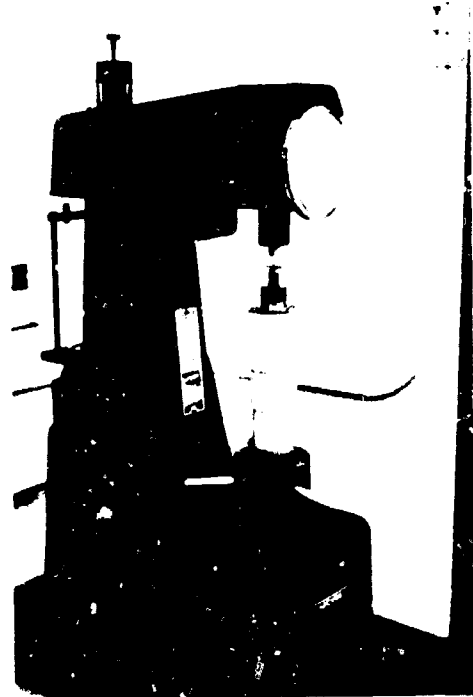


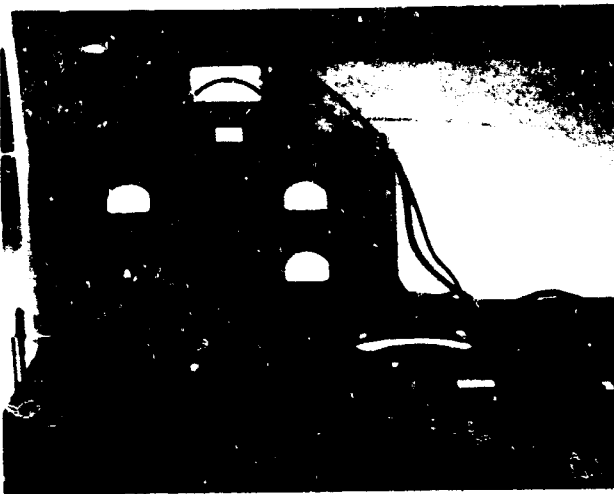
FIGURE 4      SCHEMATIC DRAWING OF ELECTRICAL CIRCUIT  
AT TYPICAL PLATING STATION.



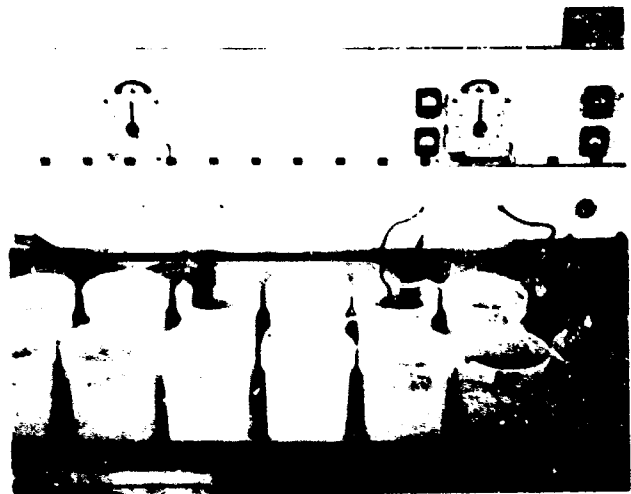
Tensile Tester  
(Crimp Evaluation)



Hardness Tester  
(Rockwell)



Electrical Conductivity  
Test Equipment



Pilot Cleaning Line

Fig. 5 - TEST EQUIPMENT AND PILOT CLEANING LINE

V.

BASIS METAL PROCUREMENT AND CONTACT DESIGN

Procurement of material and the machining of the actual piece part contacts used as test samples consumed a major portion of time. A delay in procurement of the materials was created due to the unavailability of these metals in the specific alloys outlined in the contract and due to the dimensions required for contacts. The basis metal analysis of these contacts was clearly defined and resulted from a preliminary investigation by the Air Force.

The primary reason for the difficulty in procurement of basis materials in the consistencies outlined was due to recent industrial changes in contact basis metal analysis. These changes are a result of improved electrical properties in the new alloys. Therefore, there were cases where the alloy consistency originally outlined had been discontinued. In these circumstances, we accepted the new alloys for use in our development work in place of the original material. It should be noted that these alloy changes were very slight and usually were only in the order of one to two percent of a given metal constituent. However, procurement effort was made strictly on the basis of those materials originally outlined for investigation. Any deviation in material consistency was due to its unavailability in the original consistency. The following is a chemical analysis of all material accepted for use as contact basis materials:

A. Leaded Copper

1. Round Rod - 98.77% Cu, 1.18% Pb

B. Nickel Silver

1. Round Rod - 60.2% Cu, 22.2% Zn, 17.45% Ni
2. Flat Bar - 64% Cu, 17.6% Zn, 18.3% Ni

C. Nickel Iron

1. Round Rod - 50.1% Fe, 49.8% Ni

D. Phosphor Bronze "A"

1. Round Rod - 95.3% Cu, 4.52% Sn, .16% P
2. Flat Bar - 94.94% Cu, 4.86% Sn, .18%P

#### E. Chrome Copper

1. Round Rod - 99.39% Cu, .50% Cr
2. Flat Bar - 99.49% Cu, .51% Cr

#### F. Beryllium Copper

1. Round Rod - 97.4% Cu, 1.97% Be, .35% Co, .19% Fe
2. Flat Bar - 97.4% Cu, 2% Be, .34% Co, .12% Fe

#### G. Leaded Brass

1. Round Rod - 61.4% Cu, 35.2% Zn, 3.08% Pb,  
.1% Sn, .08% Fe
2. Flat Bar - 61.18% Cu, 34.9% Zn, 3.18% Pb,  
.56% Ni, .09% Fe

A second procurement problem of contact basis materials was due to dimensional requirements of the incoming material. The contract outlined the investigation of seven contact basis metals which included three contact configurations of each material. The dimensional requirements were based on the size and type of contacts being investigated. In particular we refer to the objective of this program which is to center our investigations on MIL-C-26636 contacts. It, of course, was also necessary to investigate male and female contacts, flat contacts, and the crimp barrel end of the contacts. This required contacts or preferably piece parts simulating contacts that were round, flat, and contacts with holes. A number 16 was the contact size established for investigation during this program. When we evaluated the procurement picture for contacts, we projected all the requirements these contacts must meet through the life of this program, keeping costs at a minimum. Basically, this involved the evaluation of the number of contacts in each dimension and material for each work segment of the contract. After proper evaluation (Value Engineering) the following dimensions were arrived at for piece part contacts: First, the pin contact blanks for each material outlined were to be one inch long and .09375 inch in diameter. Approximately one-third of these contacts were to have a hole on one end which was .06325 inch in diameter, and .210 inch deep. This hole was designed to meet requirements outlined in the contract, to include a tube configuration in our tests, and to give a dimensional configuration that may be used to evaluate the cleaning, plating, and characteristic tests on an inside dimension. This enabled us to evaluate all the required tests for the female and crimp barrel ends of contacts as a function of this hole.

The dimensional design for flat contact blanks was one inch long, one-eighth wide and 3/32 inch thick. The dimensions of all parts were designed to meet the requirements of the plating, cleaning, and characteristic tests conducted throughout this program, keeping costs at a minimum.

It should be re-emphasized that actual contacts were not machined, but instead we used blanks of a like material and similar dimensional configuration. This was due to cost and the fact that it was unnecessary to have actual contacts in order to conduct most of these tests. However, it is recognized that much of the data compiled herein would be further validated if the fundamental tests were evaluated using actual connector contacts, meeting the MIL-C-26636 specification. Therefore, this company purchased 12,500 male and 12,500 female contacts for this purpose. All tests conducted herein contained a small number of actual contacts, and all final tests were run using 100% MIL-C-26636 contacts.

TABLE V

MATERIAL	HARDNESS		CRIMP RESISTANCE				TENSILE STRENGTH IN POUNDS				
	LEVEL	ROCKWELL "B"	MILLIVOLT DROP AT 5 AMPS		AUG.	% CHANGE	BEFORE TEMP. DURABILITY TEST	AUG.	AFTER TEMP. DURABILITY TEST	AUG.	% CHANGE
			BEFORE TEMP. DURABILITY TEST	AFTER TEMP. DURABILITY TEST							
LEADED COPPER	1	F 44 - 50	.525 - .60	.55	.55 - .62	.58	+5.4	56 - 62	59	50 - 51	51 - 13
	2	1/4 36 - 38	.54 - .56	.55	.65 - .70	.67	+21	66 - 74	68	48 - 54	50 - 26
	3	1/4 21 - 27	.55 - .57	.56	.63 - .71	.66	+17	66 - 69	67	56 - 60	58 - 13
CHROME COPPER	1	* 59 - 63	.64 - .72	.67	.58 - .68	.61	-8.9	61 - 67	64	45 - 54	50 - 21
	2	* 38 - 48	.56 - .64	.59	.57 - .66	.62	+5	65 - 72	69	51 - 55	52 - 24
	3	* 24 - 32	.57 - .62	.60	.57 - .71	.65	+7.6	69 - 72	70	50 - 56	53 - 24
BERYLLIUM COPPER	1	1/4 95 - 98	2.23 - 2.56	2.36	2.23 - 2.60	2.5	+5	26 - 32	30	18 - 23	20 - 33
	1	F 79 - 83	1.19 - 1.30	1.21	1.19 - 1.22	1.21	-	55 - 65	59	30 - 40	35 - 40
	2	1/4 69 - 73	1.34 - 1.55	1.41	1.23 - 1.41	1.31	-7	57 - 63	61	52 - 53	52 - 14
LEADED BRASS	3	1/4 52 - 58	1.22 - 1.30	1.27	1.35 - 1.36	1.36	+7	66 - 72	69	46 - 51	48 - 30
	1	F 95 - 100	1.68 - 1.75	1.70	1.57 - 1.75	1.69	-5	28 - 41	34	21 - 25	22 - 35
	2	1/4 88 - 91	1.72 - 1.80	1.73	1.69 - 1.81	1.73	-	42 - 52	47	31 - 36	34 - 27
PHOSPHOR BRONZE	3	1/4 79 - 83	1.68 - 1.75	1.70	1.79 - 1.96	1.87	+10	56 - 63	61	40 - 44	41 - 32
	4	* 70 - 72	1.66 - 1.78	1.71	1.72 - 2.07	1.8	+5.2	67 - 73	70	46 - 47	47 - 32
	1	* 93 - 96	6.90 - 7.40	7.10	7.30 - 8.70	7.8	+9.8	32 - 43	37	23 - 25	24 - 35
NICKEL IRON	1	F 95 - 96	3.54 - 3.86	3.68	3.37 - 3.51	3.44	-6.5	40 - 58	50	37 - 41	39 - 22
	2	1/4 82 - 86	3.32 - 3.70	3.49	3.77 - 4.02	3.87	+10	55 - 62	59	46 - 50	48 - 18
	3	1/4 69 - 71	3.41 - 3.91	3.63	3.84 - 4.66	4.18	+15	60 - 65	63	50 - 53	51 - 19
NICKEL SILVER	4	* 58 - 61	3.32 - 3.39	3.36	3.58 - 4.65	4.06	+20	56 - 62	59	48 - 51	49 - 16
	* 75 - 78		.67 - .76	.72	1.69 - 1.81	1.73	-	65 - 67	66	49 - 51	50 - 24
MIL-C-26500 CONTACTS											

\* CHROME COPPER - ARBITRARY HARDNESS LEVELS.

\* NICKEL SILVER &amp; PHOSPHOR BRONZE - LESS THAN 1/4 HARD.

\* NICKEL IRON - HARDNESS OF RECEIVED MATERIAL ONLY.

\* MIL-C-26500 CONTACTS - HARDNESS OF RECEIVED CONTACTS ONLY.  
(Tellurium Copper Contacts)

## BASIS METAL CHARACTERISTIC DATA



## VI.

### ELECTRICAL CONDUCTIVITY

Electrical conductivity was an important factor when selecting basis materials for electrical connector contacts. Therefore, an electrical conductivity test was made on all incoming contact basis material. It is recognized that the conductivity of most basis materials used in electrical connector contacts may be found in the ASM Metals Handbook. However, it was necessary to conduct a conductivity test on the included material in order to validate the fact that we were using appropriate contact material. This test enabled the reader the opportunity to more adequately compare the included data with similar investigations knowing more characteristics of the materials used. The particular basis contact materials included herein were selected by the Air Force after a preliminary investigation.

This test was a relatively simple one utilizing standard laboratory facilities and equipment. Conductivity was determined by measuring the millivolt drop of a known current across a length of material knowing the dimensions and volume of each material tested. Each test piece was one foot in length and had a cross sectional dimension of .09375 inch diameter, or .125 inch diameter (round rod); or .125 inch x .125 inch dimension (flat bar); or 1/32 inch x 3/16 inch (flat bar); or 1/32 inch x 1/8 inch (flat bar) depending on the material being tested. In each case the volume of the material was calculated for use in determining percent conductivity of those materials. There were seven materials of which five were purchased in two configurations; this resulted in twelve conductivity determinations. For each conductivity determination, there were three measurements made at two current settings.

Those currents were 10 amps DC and 5 amps DC with two of the materials also having a third test made at the 1 amp level. It was necessary for nickel iron and nickel silver to have a third test due to the fact that they have a lower conductivity and at the higher test currents, the material would heat. The individual readings for each test were then compared to see if there were any appreciable difference due to heating of the material. Two other comparisons were also made relative to this data. The first was to check the method of measuring millivolt drop by making a millivolt test on a sample of pure copper. The other comparison was to check our percent conductivity determination for each material with the handbook value of the same material. In each case all our values were comparable.

From the millivolt drop readings the percent conductivity for each material was calculated by the following formula:

$$\text{Conductance (g)} = \frac{\frac{1}{R}}{A} \text{ mhos of conductance}$$

l = Distance between test probes

R = Resistance values taken by millivolt drop test

A = Cross sectional area of test sample

Take the reciprocal of the above formula which will give you volume resistivity. This then can be compared with the IACS standard for annealed copper. Volume resistivity is a function of conductance.

Conductivity is the ratio of:  $\frac{\text{Volume Resistivity of IACS}}{\text{Volume Resistivity of the Unknown Metal}}$

The conductivity values shown below were determined using the above formulas and the accumulated data.

	<u>Rod Stock</u>		<u>Flat Stock</u>	
	<u>Test Value</u>	<u>Book Value</u>	<u>Test Value</u>	<u>Book Value</u>
Leaded Copper	99.0%	98.0%		
Leaded Brass	20.9%	26.0%	21.00%	26.0%
Nickel Silver	7.3%	6.0%	5.45%	6.0%
Nickel Iron	3.8%*	1.9%**		
Chrome Copper	94.0%		82.00%	80-90%
Phosphor Bronze	15.9%	15.0%	14.20%	15.0%
Beryllium Copper	20.0%	15-18%	21.00%	15-18%

\* Approximately

\*\* No exact book value

The instruments used for this test included:

Millivolt Meter - Universal Polyrange  
Accuracy of 1/2 of 1% of Full Scale

Ammeter - Weston - Model #931  
Accuracy of 1% of Full Scale

Current Source - Custom Built DC Rectifier  
Filtered Output Maximum 1% Ripple (Feed by  
Sola Constant Voltage Transformer - Model  
20-13-125)

The difference in some of the values between test values and book values was partially attributed to the fact that the exact alloy composition could, in many cases, not be found listed in the handbook. However, in each case, the material within the handbook chosen for comparison was relatively close as to alloy composition. It is this minor difference in alloy composition that does attribute to some of the differences in conductivity values.

## VII.

### THERMAL CONDUCTIVITY

Thermal conductivity was outlined as a characteristic check to be conducted on the seven (7) basis metals investigated. However, as the result of a preliminary investigation, it was found that a thermal conductivity test was impractical due to the requirements of the test. This conclusion was based on the following facts:

- A. That<sup>1</sup> the dimensional size of the connector contact piece parts investigated were much too small to conduct a standard thermal conductivity test on them directly.
- B. Procurement of the same material in larger dimensions were not realistic due to procurement problems. The tests were intended to be specifically correlated to the cleaning and plating test part lots.
- C. Those organizations contacted clearly stated that hand-book tables on thermal conductivity were fully reliable and adequate for our purpose.
- D. If a thermal conductivity test was conducted on this material, it would require excessive technical equipment, time and expense as compared to the standard thermal conductivity test. The time alone would be in excess of that allotted this entire work period.
- E. The ASTM standards and appropriate technical material was reviewed for an appropriate test with no avail.
- F. It was also concluded that it appears it would be extremely difficult to find an organization that would do this test, due to the results we have had after contacting the National Bureau of Standards, three University of Minnesota Laboratories, and many private organizations.

This test was deleted, therefore, from the prescribed work outline and additional emphasis was placed on other investigations.

<sup>1</sup>Robinson, H.E., Chief, Heat Transfer Section, National Bureau of Standards.

## VIII.

### HARDNESS OF BASIS MATERIALS

A preliminary hardness investigation was made on all the basis metals procured for this contract work as well as on functional surfaces that effect the characteristics and properties of contacts. This included comparative hardness readings of annealed materials.

The instrument used to make these tests was a Wilson Rockwell Tester, using the Rockwell superficial 15T Scale. The readings obtained from this were converted to Rockwell "B" Scale Values. All readings obtained from round stock, including piece parts and contacts were subject to a correction factor. This correction factor was necessary due to the fact that one does not get a true hardness reading on a curved surface. The correction figures were taken directly from a calibrated chart. It should be noted that in each hardness test three checks were made and then an average hardness was derived from the three readings.

There were two basic purposes for making hardness measurements during this early contract phase. The first reason being to further define the properties of the basis materials that were investigated and, therefore, have further data on hardness measurements in conjunction with electrical conductivity, ductility, metal cleaning, and crimp evaluation tests. These tests were made so that the reader would know the exact material used and its characteristics. The reader would also be able to evaluate and better understand the importance and the direct relation there is between the different physical properties of the basis metals used in the making of electrical connector contacts.

The second reason for hardness tests was to determine hardness levels of individual materials after annealing. This work was performed in conjunction with the crimp evaluation tests discussed within this report. In this case, we attempted to get different hardnesses of each material (1/4, 1/2 and 3/4 hard), whereby we then ran crimp evaluation, ductility, and stress experiments at these hardnesses. Our objective was to determine a comparative crimp evaluation rating as a function of the different hardness levels for the contact basis materials investigated. A Rockwell "B" check on all of the annealed materials was necessary in order that we could determine the hardness range acquired after a given annealing cycle. An analysis of the hardness tests, along with relative hardness data, is included in the section of this Report titled "Crimp Evaluation."

As stated, the approach taken by this contractor was to acquire different hardness levels of each material by annealing. The annealing temperatures as well as the appropriate Rockwell "B" hardness figures for 1/4, 1/2, 3/4 and full hard of each material, were taken from the ASM Metals Handbook. Where no Rockwell "B" hardness figures were given or where no annealing cycles were included, we experimented with many annealing cycles trying to determine the appropriate annealing cycle for a given hardness range. Where no Rockwell "B" hardness figures were included for a given hardness range, we took hardness figures of the same material, but at different hardness levels and interpolated in order to get the hardness required to match the 1/4, 1/2, or 3/4 hard levels.

From the approach outlined above, there were two points considered. The first was that the method used in determining hardness (Rockwell "B") figures for appropriate hardness levels were not completely adequate, however, it was the only method available to us. The second consideration was that the physical properties of a material at a given hardness level could be slightly different depending on whether or not the hardness level was acquired by annealing or cold working the material. Annealed material, as compared to cold worked material of the same hardness, would possibly have a larger grain size and a lower tensile strength. It was impractical for us to evaluate cold worked material. All of the included data was functional and relative when compared within the perimeters of this investigation. Even though there was a comparative difference in tensile strength and grain size for a given hardness of material depending on how that hardness was acquired, a comparison of the relative data was appropriate.

The Rockwell "B" hardness readings of all incoming basis material for this program are included below:

ACTUAL HARDNESS OF RAW MATERIAL RECEIVED

<u>Material</u>	<u>Hardness</u>	
	<u>Level</u>	<u>Rockwell "B"</u>
Leaded Copper	F	47-50
Chrome Copper	*	59-65
Beryllium Copper	1/2	93-99
Leaded Brass	F	78-84
Phosphor Bronze	F	95-100
Nickel Iron	*	90-92
Nickel Silver	F	90-92
MIL-C-26500 Contacts	*	75-78

- \* Chrome Copper - Arbitrary Hardness Levels
- \* Nickel Iron - Hardness of Received Material
- \* MIL-C-26500 Contacts - Hardness of Received Material

## IX.

### BASIS METAL CLEANING

Due to the fact that metal cleaning has the greatest effect on quality electroplating, it was felt that a comprehensive introduction was necessary to this subject. Therefore, in the reporting of our metal cleaning investigation we have included a brief abstract so that the reader may better understand the science of metal cleaning as well as the approach and results reported herein,

One of the first aspects considered under metal cleaning was a test for cleanliness. It was recognized that regardless of how fine a cleaning cycle was established, without a method of evaluating the degree of cleanliness, the whole preliminary cleaning process was meaningless. As a result of our Literature Search we concluded that the Water Break Test was the ultimate in the tests for cleanliness. However, there were two relative approaches considered. One was that the Water Break Test could be conducted in a number of ways, with one procedure being more accurate than the others. However, the more elaborate the Water Break Test, the more time and equipment it required. A second test for metal cleanliness was a plating adherence test. The purpose of this test was to check the adherence of an electroplated layer to a freshly cleaned metal surface. Basis metals were considered adequately cleaned if the plating layer properly adhered.

As a result of the Literature Search and due to practical experience, it was felt that the adherence test was a comparable cleanliness test and it would substantiate and complement the results from the Water Break Test.

The following tests<sup>2</sup> for cleanliness were evaluated in the "Electroplaters' Process Control Handbook" by Foulke, D. G. and Crane, F. D. They tested for cleanliness sensitivities on low carbon, matte-surface steel soiled with lard oil. The following are the results of these tests:

<u>Test</u>	<u>Sensitivity (g/cm<sup>2</sup>)</u>
Atomizer	$0.7 \times 10^{-7}$
Water Break	$6.7 \times 10^{-7}$
Fluorescent Dye	$270.0 \times 10^{-7}$
Copper Sulfate Dip	$320.0 \times 10^{-7}$
Potassium Ferricyanide Paper	$300.0 \times 10^{-7}$

<sup>2</sup>Linford, H. B. and Saubestre, E. B., Plating, 40, 489, 633 (1953)

The<sup>2</sup> sensitivity of the atomizer test of Linford and Sanbestre is a function of both the surface condition of the metal and the chemical nature of the contaminant. The sensitivity measurements were made by depositing known weights of soil on a known area of substrate. Small quantities of soil were applied by using extremely dilute solutions of the soil in very clean solvent. The sensitivity of the atomizer test on low carbon, matte-surface steel is tabulated below:

<u>Type of Soil</u>	<u>Name</u>	<u>Sensitivity (g/cm<sup>2</sup>)</u>
Fatty Acid	Stearic Acid	0.2 x 10 <sup>-7</sup>
Fatty Ester	Lard Oil	0.7 x 10 <sup>-7</sup>
Medium Oil	SAE 50 Motor Oil	1.2 x 10 <sup>-7</sup>
Parafinic Ash	Mineral	3.0 x 10 <sup>-7</sup>

The Water Break Test is one of the older, more readily applied tests for cleanliness of metal surfaces. One has only to observe whether a continuous water film is sustained by the metal surface. This test has been made quantitative by allowing the sample to drain in a vertical position for twenty seconds, at which time it is sprayed by an atomizer.<sup>3</sup> Those areas in which the water film breaks sustain droplets become coalescent with the film already present. This, in effect, freezes the Water Break Test at the twenty-second level and allows a quantitative evaluation of the percent of the area that is clean in a manner analogous to that described under the atomizer test.

The following is a brief description of the clean sensitivity test evaluated herein:

#### Fluorescent Dye<sup>4</sup>

In this test a fluorescent dye is dissolved in the soil and the degree with which this soil is removed is measured by photographing the specimen in ultraviolet light.

#### Copper Galvanic Replacement

The area covered by an adherent copper plate when immersed in a copper sulfate solution is a measure of the cleanliness of the plate.

<sup>2</sup>Linford, H. B. and Saubestre, E. B., Plating, 40, 489, 633 (1953)

<sup>3</sup>Spring, Dr. S., Metal Finishing, 50, No. 2 (1952)

<sup>4</sup>Foulke, D. G. and Crane, F. D., Electroplaters' Process Control Handbook, 132 (1963)



### Potassium Ferricyanide Paper

When a paper treated with potassium ferricyanide is placed in contact with an iron or steel panel, clean areas will show dark blue, whereas oil droplets will register colorless or yellowish spots on the paper. This can be used as a quantitative test for measuring percentage of clean area.

### Gravimetric

In this test clean ether is used to wash the panel. The resultant contaminated solution is then evaporated in a tared watch glass. From this the total weight of soil removed from the panel is determined. This test will not give a measure of the fraction of the area remaining soiled.

### Radioactive Tracer

Directly comparative data of the radio active tracer technique are not available. In this technique, the soil is compounded with an organic compound containing some carbon 14. This technique has the greatest ultimate sensitivity, as currently constituted, but it is not generally used in the metal finishing industry because of equipment costs and the need for specialized operators.

Our purpose was to propose and prepare cleaning procedures that are adaptable to the average electroplating facility and yet be 100 percent efficient as a cleaning process. These processes must be capable of removing contamination and oxides as well as to react favorably with one or all of the seven (7) contact base metals considered within this contract.

Metal<sup>5</sup> cleaning is a very general term, covering the preparation of metal surfaces for a variety of finishing processes. This particular section will restrict itself to the discussion of cleaning metals with chemical agents in preparation for electroplating. The same general principles will apply, however, to the preparation for other finishing steps, only the degree of cleanliness required is different. A surface that will permit high quality, adherent, plated deposits will usually be suitable for any other finishing or coating process because of the level of cleaning required to achieve this. Due to the rigid requirements that cleaning of metals prior to electroplating generally require, a multi-stage procedure similar to the one that follows is necessary for proper cleaning.

<sup>5</sup>Spring, Dr. S., "Metal Cleaning", Metal Finishing Guide Book Directory, 212 (1961)

- A. Precleaning -- vapor degreasing, solvent, emulsifiable solvent, or emulsion treatment.
- B. Intermediate cleaning -- alkaline bath treatment in spray, barrel or immersion equipment.
- C. Electroplating -- alkaline bath anodic or cathodic (or both) treatment.
- D. Chemical cleaning -- acid cleaning and polishing.
- E. Activation -- for plating, usually a particular acid clean.

The division of these stages varies in commercial practice. Some plants use a spray alkaline cleaning instead of solvent cleaning as the precleaning stage. With specially designed vapor degreasing equipment, some plants go directly from solvent type cleaning to the electrocleaners.

It would not be expected that one cleaning process will meet all of the above conditions, however, by incorporating two or three changes in a process, or by incorporating two or three individual cleaning processes, it is then possible to meet the requirements for cleaning set forth herein.

The<sup>6</sup> choice of cleaning materials depends largely on six major factors: nature of the dirt; the effect of the chemicals on the metals to be cleaned; the degree of cleanliness required; and the method of application, safety, and cost.

Solvent degreasing is used to remove the bulk of soils readily soluble in chlorinated hydrocarbons such as inhibited trichloroethylene or perchlorethylene. In most cases, an alkaline degreasing will follow the solvent treatment to remove solid particles or other soils insoluble in chlorinated hydrocarbons.

A good alkaline cleaning material must be readily soluble in water and its solutions must possess superior ability to wet the surface of the metal being cleaned; to wet and penetrate the dirt being removed; to dissolve or saponify animal and vegetable oils and greases or temporarily to emulsify and suspend the insoluble or unsaponifiable oils and solid particle dirt; to soften water and

<sup>6</sup>Graham, A. K., Electroplating Engineering Handbook, 141-143 (1955)

prevent attack or tarnish of the metal surface; to neutralize acidic substances introduced with the solid metal; and to remove the dirt efficiently in a reasonable time with average equipment.

### Saponification

Alkaline solutions partially saponify oils and greases that can be converted into water-soluble soaps. This action assists in the removal of most animal and vegetable oils used in drawing and various machining operations.

### Wetting and Emulsification

Soaps and other wetting agents lower the surface tension of the water to the approximate level of the surface tension of the oils, and thus lower the interfacial tension between the oils and the cleaning solution.

### Pickling<sup>7</sup>

Pickling is the process used to remove scale, corrosion products and oxides from the surface of metals. Bright dipping is generally understood to be pickling of non-ferrous metals resulting in clean bright surfaces, though not necessarily lustrous. The use of chemical pickling has been general for non-ferrous and light metals whereas electrolytic and chemical pickling are used for low carbon and alloy steels. Electrolytic processes for non-ferrous metals are not used in various cleaning and polishing applications.

Chemical pickling in general may be represented by the following equation:



M = The Metal

HX = The Acid

The rate of pickling\* can usually be controlled by controlling the concentration and temperature of the pickle. Electrolytic pickling is sometimes preferred because the extent of pickling is proportional to the immersion time. In chemical pickling the reaction indicated in the following equation:



<sup>7</sup>Modjerka, R. S., "Pickling and Bright Dipping", Electroplaters' Process Control Handbook, 134, (1963)

\*Alkali Derusters are not Included in this Discussion.

is undesirable, hence inhibitors are added to keep this action to a minimum.

The selection of an appropriate cleaning method in a given situation depends on a number of factors, the type and amount of soils; the base metal composition and surface finish; and the degree of cleanliness required. Particular consideration should also be given to types of equipment available; cost; quantities involved; disposal problems; personnel; etc.

## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: LEADED BRASS

SEQUENCE NO. 1

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 Sec. Vapor, 30 Sec. Spray, 3 Min. Ultrasonic. Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts 3 Min. Cathodic, 2 Min Anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Nitric	1 Min.	Room Temp. Note 4
6	Rinse	1 Min.	80°F +/- 5°F Note 3
7	Ammonium Persulfate	20 Sec.	Room Temp. Note 5
8	Rinse	30 Sec.	80°F +/- 5°F. Note 3
9	Bright Dip 19A	10 Sec.	Room Temp. Note 6
10	Rinse	30 Sec.	80°F +/- 5°F Note 3
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Fluoboric Acid	1 Min.	140°F +/- 5°F Note 7
13	Rinse	1 Min.	80°F +/- 5°F Note 3
14	Inspect Sample of Lot Under 20X Microscope.		Note 8
15	Load Tumbler		
16	Rinse	30 Sec.	80°F +/- 5°F Note 3 Note 9
17	Cyanide	15 Sec.	Room Temp. Note 10
18	Rinse	30 Sec.	80°F +/- 5°F Note 3 Note 9
19	Ready for Plating		

Notes on Leaded Brass - Sequence Number 1

1. Spray and ultrasonic steps are optional, however, if they are not used the vapor time must be at least three minutes. Parts to be held in stainless steel baskets throughout clean sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temp</u>
Detrex B	1½ Lbs. Per Gal.	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Fluoboric-Nitric

<u>Make Up</u>	<u>Amount</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	Room
42°Baume - Nitric Acid	12% by Volume	Room
Water	76% by Volume	Room

5. Ammonium Persulfate

<u>Make Up</u>	<u>Amount</u>	<u>Operating Temperature</u>
Ammonium Persulfate	1½ Lbs. Per Gal	Room

This solution will chemically break down and must be remade weekly or sooner depending on use.

6. Bright Dip 19A

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
66° Baume-Sulfuric Acid	2510 ML	Room
42° Baume-Nitric Acid	426 ML	
18° Baume-Hydrochloric Acid	12 ML	
Copper Sulfate	1 Gram	
Water	2946 ML	

Ventilation Required. Parts must be rinsed immediately after dipping in this solution. If parts are allowed to gas in air, they will pit badly.

7. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% by Volume	

Ventilation Required.

8. Inspect sample of lot under 20X microscope for burrs, scale, pitting, etching and rinsing in holes. If parts have burrs, hold for quality control evaluation. If parts have scale, then repeat Steps 4 through 11 and re-inspect. If pitting or etching is severe, check for contaminated or over heated cleaning solutions. If rinsing is a problem, increase rinsing time and part movement. Also try alternate hot and cold water rinses. After inspecting samples, they should be degreased, rinsed, dipped in Fluoboric (Step 12) for 30 seconds and returned to lot. Then continue with Step 15.

9. Tumbler should be rotating in this rinse.

10. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. Per Gal.	Room

Tumbler should be rotating in this solution.

## CLEANING SEQUENCE

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MATERIAL: BERYLLIUM COPPER

SEQUENCE NO. 2

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 Sec. Vapor, 30 Sec. Spray, 3 Min. Ultra-sonic Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts 3 Min. Cathodic, 1 Min Anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Acid	1 Min.	140°F +/- 5°F Note 4
6	Rinse	1 Min.	80°F +/- 5°F Note 3
7	Sulfuric Acid	1 Min.	135°F +/- 5°F Note 5
8	Rinse	1 Min.	80°F +/- 5°F Note 3
9	Heat Treated Parts		Note 6
		(Approx)	
10	Bright Dip 19B	1 Min.	105°F +/- 5°F Note 7
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Rinse	30 Sec.	80°F +/- 5°F Note 3
13	Fluoboric Acid	30 Sec.	140°F +/- 5°F Note 4
14	Rinse	30 Sec.	80°F +/- 5°F Note 3
15	Inspect Parts Under 20X Microscope		Note 8
16	Load Tumbler		
17	Rinse	30 Sec.	80°F +/- 5°F Note 3 Note 9
18	Cyanide	15 Sec.	Room Temp. Note 10
19	Rinse	30 Sec.	80°F +/- 5°F Note 3-9
20	Ready for Plating		



Notes on Beryllium Copper - Sequence Number 2

1. Spray and ultrasonic steps are optional, but if not used the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequences. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as a liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Made Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. Per Gallon	198°F +/- 5°F

In any alkaline soap cleaner, parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report, which discusses rinsing practices.

4. Fluoboric Acid

<u>Make Up</u>	<u>Amount</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% by Volume	

Ventilation required.

5. Sulfuric Acid

<u>Make Up</u>	<u>Amount</u>	<u>Operating Temperature</u>
66° Baume-Sulfuric Acid	25% by Volume	130°F-140°F
Water	75% by Volume	

Ventilation required.

6. On heat treated parts, repeat Steps 4 through 8 two more times.

7. Bright Dip 19B

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
75% Phosphoric Acid	14,700 ML	105°F +/- 5°F
42° Baume-Nitric Acid	5,400 ML	
Glacial Acetic Acid	6,400 ML	
18° Baume-Hydrochloric Acid	150 ML	
Water	50 ML	

Ventilation required. Vigorous gassing occurs. Parts should be dipped 20 seconds then rinsed immediately. If allowed to gas in air, the parts will become badly pitted. After dipping for 20 seconds, sample parts must be checked with a micrometer to determine amount of metal removed per surface in 20 seconds. Total metal removal should be .0005" per surface. This may take 2 to 4 dips. Do not bright dip more than 20 seconds per dip because vigorous gassing of chemical reaction causes heating of solution which in turn increases rate of removal and pitting.

8. Inspect sample of parts under 20X Microscope for burrs, scale, pitting, etching and rinsing in holes. If parts have burrs, hold for quality control evaluation. If parts have scale, repeat steps 4 through 8, and reinspect. If pitting or etching is severe, check for contaminated or overheated cleaning solutions. If rinsing is a problem, increase rinsing time and part movement. Also try alternate hot and cold rinses. After inspecting samples, they should be degreased, rinsed, dipped in Fluoboric (Step 13) for 1/2 minute and return to lot. Continue with Step 16.
9. Tumbler should be rotating in this rinse.
10. Cyanide Dip (Sodium or Potassium).

<u>Make Up</u>	<u>Quantity</u>
Potassium Cyanide	8 Oz. Per Gal.

Tumbler should be rotating while in this solution.

## CLEANING SEQUENCE

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MATERIAL: PHOSPHOR BRONZE

SEQUENCE NO. 3

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 Sec. vapor, 30 Sec. Spray, 3 Min. Ultra-sonic. Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts, 3 Min. Cathodic, 1 Min. Anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Nitric	1 Min.	Room Temp. Note 4
6	Rinse	1 Min.	80°F +/- 5°F Note 3
7	Ammonium Persulfate	30 Sec.	Room Temp. Note 5
8	Rinse	1 Min.	80°F +/- 5°F Note 3
9	Bright Dip 19C	10 Sec.	Room Temp. Note 6
10	Rinse	30 Sec.	80°F +/- 5°F Note 3
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Fluoboric Acid	20 Sec.	140°F +/- 5°F Note 7
13	Rinse	1 Min.	80°F +/- 5°F Note 3
14	Inspect sample of Lot under 20X Microscope		Note 8
15	Load Tumbler		
16	Rinse	30 Sec.	80°F +/- 5°F Note 3&9
17	Cyanide	15 Sec.	Room Temp. Note 10
18	Rinse	30 Sec.	80°F +/- 5°F Note 3&9
19	Ready for Plating		

Notes on Phosphor Bronze - Sequence Number 3

1. Spray and ultrasonic steps are optional, but if not used the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. per Gallon	198°F +/- 5°F

In any alkaline soap cleaner, parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Fluoboric-Nitric

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48%-50% Fluoboric Acid	12% by Volume	Room
42°Baume Nitric Acid	12% by Volume	
Water	76% by Volume	

5. Ammonium Persulfate

<u>Make Up</u>	<u>Quantity</u>
Ammonium Persulfate	1½ Lbs. Per Gal.

This solution chemically breaks down and must be remade weekly or sooner depending on use.

6. Bright Dip 19C

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
66°Baume-Sulfuric Acid	7 Pints	Room
42°Baume-Nitric Acid	7 Pints	
Water	7 Pints	
18°Baume-Hydrochloric Acid	15 ML	
Copper Sulfate	2 Grams	
Carbon	3 Grams	

Ventilation required. Parts should be bright dipped for 5 seconds then rinsed immediately so as not to cause pitting in air. Then bright dipped again for 5 seconds and rinsed immediately.

7. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>
48% Fluoboric Acid	12% by Volume
Water	88% by Volume

Ventilation required.

8. Inspect sample of parts under 20X Microscope for burrs, scale, pitting, etching and rinsing in holes. If parts have burrs, hold lot for quality control evaluation. If parts have scale, repeat steps 4 through 8 and reinspect. If pitting and etching is severe, check for contaminated or overheated cleaning solutions. If rinsing is a problem increase rinsing time and part movement; also try alternate hot and cold water rinses. After inspecting samples, they should be degreased, rinsed, dipped in Fluoboric Acid (Step 12) for 1/2 minute and returned to lot. Continue with Step 14.

9. Tumbler should be rotating in this rinse.

10. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>
Potassium Cyanide	8 Oz. Per Gallon

Tumbler should be rotating in this solution.

## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: NICKEL-IRON

SEQUENCE NO. 4

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 Sec. Vapor, 30 Sec. Spray, 3 Min. Ultra-sonic Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts 3 Min. Cathodic, 1 Min Anodic Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Bright Dip 19D	20 Sec.	Room Temp. Note 4
6	Rinse	30 Sec.	80°F +/- 5°F Note 3
7	Rinse	30 Sec.	80°F +/- 5°F Note 3
8	Cyanide	30 Sec.	Room Temp. Note 5
9	Rinse	1 Min.	80°F +/- 5°F Note 3
10	Fluoboric Acid	30 Sec.	140°F +/- 5°F Note 6
11	Rinse	1 Min.	80°F +/- 5°F Note 3
12	Inspect Sample of Lot Under 20X Microscope		Note 7
13	Rinse	30 Sec.	80°F +/- 5°F Note 3
14	Hydrochloric Acid	1 Min.	Room Temp. Note 8
15	Rinse	1 Min.	80°F +/- 5°F Note 3
16	Ferric Sulfate	20 Sec.	Room Temp. Note 9
17	Rinse	30 Sec.	80°F +/- 5°F Note 3
18	Load Tumbler		
19	Rinse	30 Sec.	80°F +/- 5°F Note 3-10
20	Ready for Plating		

Notes on Nickel-Iron - Sequence Number 4

1. Spray and ultrasonic steps are optional, but if not used, the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene, or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. Per Gallon	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Bright Dip 19D

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Glacial Acetic Acid	1440 ML	Room
42°Baume-Nitric Acid	500 ML	
18 Baume-Hydrochloric Acid	30 ML	

Ventilation required. Vigorous gassing occurs. Parts should be dipped for 10 seconds in this bright dip and rinsed immediately to prevent pitting in air. Then the parts should be dipped another 10 seconds in the bright dip and rinsed immediately. This solution must be made up daily because the acetic acid will take on moisture from the air.

5. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. Per Gallon	Room

6. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% by Volume	

Ventilation required.

7. Inspect sample of parts under 20X microscope for burrs, scale, pitting, etching, and rinsing in holes. If parts have burrs, hold lot for quality control evaluation. If parts have scale repeat steps 7 through 11 and reinspect. If pitting and etching are severe check for contaminated or overheated cleaning solutions. If rinsing is a problem increase rinsing time and part movement. Also try alternate hot and cold water rinses. After inspecting samples they should be degreased, rinsed, dipped in Fluoboric Acid (Step 10) for 1/2 minute and returned to lot. Continue with Step 13.

8. Hydrochloric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
18°Baume-Hydrochloric Acid	16% by Volume	Room
Water	84% by Volume	

Ventilation required.

9. Ferric Sulfate

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
66°Baume-Sulfuric Acid	13 oz/gal by wt	Room
Ferric Sulfate	13 oz/gal	

10. Tumbler should be rotating in this rinse.



## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: NICKEL-SILVER

SEQUENCE NO. 5

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 sec. vapor, 30 sec. spray, 3 min. ultra-sonic. Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts 3 Min. Cathodic, 1 Min Anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Bright Dip 19E	10 Sec.	145°F +/- 5°F Note 4
6	Rinse	30 Sec.	80°F +/- 5°F Note 3
7	Rinse	30 Sec.	80°F +/- 5°F Note 3
8	Cyanide	30 Sec.	Room Temp. Note 5
9	Rinse	1 Min.	80°F +/- 5°F Note 3
10	Ammonium Persulfate	15 Sec.	Room Temp. Note 6
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Hydrochloric Acid	1 Min.	Room Temp. Note 7
13	Rinse	30 Sec.	80°F +/- 5°F Note 3
14	Inspect sample of lot under 20X Microscope		Note 8
15	Load Tumbler		
16	Rinse	30 Sec.	80°F +/- 5°F Note 3&9
17	Ready for Plating.		

Notes on Nickel-Silver - Sequence Number 5

1. Spray and ultrasonic steps are optional, but if not used, the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1¼ Lbs. Per Gallon	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report, which discusses rinsing practices.

4. Bright Dip 19E

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
42°Baume-Nitric Acid	1600 ML	145°F +/- 5°F
75% Phosphoric Acid	1200 ML	
Glacial Acetic Acid	1200 ML	
Sodium Chloride	52 Grams	

Ventilation required. Gassing is extremely vigorous in this solution. Parts should be dipped 10 seconds then rinsed immediately. If allowed to gas in the air, the parts will become pitted. After dipping 10 seconds a sample of the lot should be checked with a micrometer to determine amount of metal removed per surface in 10 seconds. Total metal removal is to be .001" per surface. Do not bright dip more than 10 seconds per dip because the vigorous gassing of the chemical reaction causes overheating of the solution which in turn increases rate of removal and pitting.

5. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. Per Gallon	Room

6. Ammonium Persulfate

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Ammonium Persulfate	1½ Lbs. Per Gallon	Room

7. Hydrochloric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
18° Baume-Hydrochloric Acid	16% by Volume	Room
Water	84% by Volume	

Ventilation required.

8. Inspect sample of parts under 20X Microscope for burrs, scale, pitting, and etching and rinsing in holes. If parts have burrs, hold lot for quality control evaluation. If parts have scale repeat Steps 6 through 11 and reinspect. If pitting and etching are severe check for contaminated or overheated cleaning solutions. If rinsing is a problem increase rinsing time and part movement. Also try alternate hot and cold rinses. After inspecting sample parts they should be degreased, rinsed, dipped in Hydrochloric Acid (Step 12) for 30 seconds and returned to the lot. Continue with Step 15.

9. Tumbler should be rotating in this rinse.

## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: CHROME-COPPER

SEQUENCE NO. 6

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 sec. vapor, 30 sec. spray, 3 min. ultra-sonic. Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts, 3 Min. cathodic, 1 Min. anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Acid	30 Sec.	140°F +/- 5°F Note 4
6	Rinse	1 Min.	80°F +/- 5°F Note 3
7	Ammonium Persulfate	30 Sec.	Room Temp. Note 5
8	Rinse	30 Sec.	80°F +/- 5°F Note 3
9	Bright Dip 19B	1 Min.	105°F +/- 5°F Note 6
10	Rinse	30 Sec.	80°F +/- 5°F Note 3
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Flucboric Acid	1 Min.	140°F +/- 5°F Note 4
13	Rinse	30 Sec.	80°F +/- 5°F Note 3
14	Inspect Sample of Lot Under 20X Microscope		Note 7
15	Load Tumbler		
16	Rinse	30 Sec.	80°F +/- 5°F Note 3&8
17	Cyanide	30 Sec.	Room Temp. Note 9
18	Rinse	30 Sec.	80°F +/- 5°F Note 3&8
19	Ready for Plating		

Notes on Chrome-Copper - Sequence Number 6

1. Spray and ultrasonic steps are optional, but if not used the vapor time must be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. Per Gallon	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processer should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% by Volume	

Ventilation required.

5. Ammonium Persulfate

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Ammonium Persulfate	1½ Lbs. per Gal.	Room

This solution chemically breaks down and must be remade weekly or sooner depending on use.

6. Bright Dip 19B

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
75% Phosphoric Acid	14,700 ML	105°F +/- 5°F
42°Baume-Nitric Acid	5,400 ML	
Glacial Acetic Acid	6,400 ML	
18°Baume-Hydrochloric Acid	150 ML	
Water	50 ML	

Ventilation required. Vigorous gassing occurs. Parts should be dipped 20 seconds then rinsed immediately. If allowed to gas in air, the parts will pit badly. After dipping the parts must be checked with a micrometer to determine the amount of metal removed. Total metal removal should be .0005" per surface. Do not bright dip more than 20 seconds per dip because the chemical reaction in this solution causes heating, which in turn increases the rate of removal and pitting.

7. Inspect sample of lot under 20X Microscope for burrs, scale, pitting, etching, and rinsing in holes. If parts have burrs, hold lot for quality control evaluation. If parts have scale repeat Steps 4 through 8 and reinspect. If pitting or etching are severe, check for contaminated or overheated cleaning solutions. If rinsing is a problem increase time and part movement. Also try alternate hot and cold rinses. After inspecting samples they should be degreased, rinsed, dipped in Fluoboric Acid (Step 12) for 30 seconds and returned to lot. Continue with Step 15.

8. Tumbler should be rotating in this rinse.

9. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. per Gallon	Room

## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: LEADED COPPER

SEQUENCE NO. 7

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 sec. vapor, 30 sec. spray, 3 min. ultra-sonic. Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts, 3 Min Cathodic, 1 Min. Anodic. Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Acid-Nitric Acid	1 Min.	Room Temp. Note 4
6	Rinse	30 Sec.	80°F +/- 5°F Note 3
7	Ammonium Persulfate	20 Sec.	Room Temp. Note 5
8	Rinse	30 Sec.	80°F +/- 5°F Note 3
9	Bright Dip 19B	(Approx) 2 Min.	105°F +/- 5°F Note 6
10	Rinse	30 Sec.	80°F +/- 5°F Note 3
11	Rinse	30 Sec.	80°F +/- 5°F Note 3
12	Fluoboric Acid	30 Sec.	140°F +/- 5°F Note 7
13	Rinse	30 Sec.	80°F +/- 5°F Note 3
14	Ammonium Persulfate	15 Sec.	Room Temp. Note 5
15	Rinse	30 Sec.	80°F +/- 5°F Note 3
16	Inspect Sample of Lot under 20X Microscope		Note 8
17	Load Tumbler		
18	Rinse	30 Sec.	80°F +/- 5°F Note 3
19	Cyanide	15 Sec.	Room Temp. Note 10
20	Rinse	30 Sec.	80°F +/- 5°F Note 3&9
21	Ready for Plating		

Notes on Leaded Copper - Sequence Number 7

1. Spray and ultrasonic steps are optional, but if not used, the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. per Gallon	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processor should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Fluoboric-Nitric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	Room
42° Baume-Nitric Acid	12% by Volume	
Water	76% by Volume	

5. Ammonium Persulfate

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Ammonium Persulfate	1½ Lbs. Per Gallon	Room

This solution chemically breaks down and must be remade weekly or sooner depending on use.



6. Bright Dip 19B

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
75% Phosphoric Acid	14,700 ML	105°F +/- 5°F
42° Baume-Nitric Acid	5,400 ML	
Glacial Acetic Acid	6,400 ML	
18° Baume-Hydrochloric Acid	150 ML	
Water	50 ML	

Ventilation required. Parts should be dipped 20 seconds and rinsed immediately. If allowed to gas in air, they will pit badly. After dipping 20 seconds a sample of the lot must be checked with a micrometer to determine amount of metal removed per surface. Total metal removed should be .001" per surface. This may take 5 to 8 dips. Do not bright dip more than 20 seconds per dip because the chemical reaction causes heating of the solution which in turn increases rate of removal and pitting.

7. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% by Volume	

Ventilation required.

8. Inspect sample of lot under 20X Microscope for burrs, scale, pitting, etching and rinsing in holes. If parts have burrs hold lot for quality control evaluation. If parts have scale repeat Steps 4 through 8 and reinspect. If pitting or etching are severe check for contaminated or overheated cleaning solutions. If rinsing is a problem increase rinsing time and part movement. Also try alternate hot and cold rinses. After inspecting samples they should be degreased, rinsed, dipped in Fluoboric Acid (Step 12) for 30 seconds and returned to lot. Continue with Step 17.

9. Tumbler should be rotating in this rinse.

10. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. per Gallon	Room

Tumbler should be rotating in this solution.

## CLEANING SEQUENCE

AF 33(657)-9752

MATERIAL: TELLURIUM COPPER

SEQUENCE NO. 8

Sequence Number	Description	Time	Remarks
1	Solvent Degreaser	4 Min.	30 sec. vapor, 30 sec spray, 3 min ultra-sonic Note 1
2	Alkaline Soap Cleaner	4 Min.	198°F +/- 5°F, 6 Volts, 3 Min. Cathodic, 1 Min Anodic Note 2
3	Rinse	30 Sec.	80°F +/- 5°F Note 3
4	Rinse	30 Sec.	80°F +/- 5°F Note 3
5	Fluoboric Acid	1 Min.	140°F +/- 5°F Note 4
6	Rinse	1 Min.	80°F +/- 5°F Note 3
7	Ammonium Persulfate	20/30 (Sec)	Room Temp. Note 5
8	Rinse	1 Min.	80°F +/- 5°F Note 3
9	Bright Dip 19E	20 Sec.	150°F +/- 5°F Note 6
10	Rinse	1 Min.	80°F +/- 5°F Note 3 Rinse immediately to prevent pitting in the air.
11	Fluoboric Acid	1 Min.	140°F +/- 5°F Note 4
12	Rinse	30 Sec.	80°F +/- 5°F Note 3
13	Inspect Sample of Lot under 20X Microscope.		Note 7
14	Load Tumbler		
15	Rinse	30 Sec.	80°F +/- 5°F Note 3&8
16	Cyanide	30 Sec.	Room Temp. Note 9
17	Rinse	30 Sec.	80°F +/- 5°F Note 3&8
18	Ready for Plating		

Notes on Tellurium Copper - Sequence Number 8

1. Spray and ultrasonic steps are optional, but if not used the time in vapor should be at least 3 minutes. Parts to be held in stainless steel basket throughout sequence. It is suggested that trichlorethylene or as a second choice perchlorethylene be used as the liquid solvent.
2. This bath should be an alkaline soap cleaner suitable for industrial cleaning. An example of this would be the product manufactured by Detrex Corporation called Detrex B.

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Detrex B	1½ Lbs. Per Gallon	198°F +/- 5°F

In any alkaline soap cleaner parts should be agitated well enough to cause part movement, however, caution should be taken to prevent scratches or nicks in parts. Similar agitation practices should be used in all rinse tanks.

3. Rinsing

The plating processer should determine the flow rate of his rinses from Section X of this report which discusses rinsing practices.

4. Fluoboric Acid

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
48% Fluoboric Acid	12% by Volume	140°F +/- 5°F
Water	88% By Volume	

Ventilation required.

5. Ammonium Persulfate

<u>Make Up</u>	<u>Quantity</u>
Ammonium Persulfate	1½ Lbs. per Gallon

This solution chemically breaks down and must be remade weekly or sooner depending on use.

6. Bright Dip 19E

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
42° Baume-Nitric Acid	1600 ML	150°F +/- 5°F
75% Phosphoric Acid	1200 ML	
Glacial Acetic Acid	1200 ML	
Sodium Chloride	52 Grams	

Ventilation required. Parts should be dipped for 10 seconds in this bright dip and rinsed immediately to prevent pitting in air. Then the parts should be dipped another 10 seconds in the bright dip and rinsed immediately.

7. Inspect sample of parts under 20X Microscope for burrs, scale, pitting, etching and rinsing in holes. If parts have burrs hold lot for quality control evaluation. If parts have scales repeat Steps 7 through 12 and reinspect. If pitting and etching are severe check for contaminated or overheated cleaning solutions. If rinsing is a problem increase rinsing time and part movement. Also try alternate hot and cold water rinses. After inspecting samples they should be degreased, rinsed, dipped in Fluoboric Acid (Step 11) for 1/2 minute and returned to the lot. Continue with Step 15.

8. Tumbler should be rotating in this rinse.

9. Cyanide (Sodium or Potassium)

<u>Make Up</u>	<u>Quantity</u>	<u>Operating Temperature</u>
Potassium Cyanide	8 Oz. per Gallon	Room

X.

### RINSING PRACTICES

The necessity of proper rinsing is certainly of utmost concern to any plater; yet the average plater seldom utilizes rinsing principles to the extent that quantitative estimates of rinsing contamination are known. In the interest of establishing rigid quality control we present a summary of principles and a procedure for determining proper flow rates in rinse tanks.

This work utilizes the theoretical principle of instantaneous mixing which was applied to determine proper flow rate for each rinse. In addition, a tabulation of experimentally determined dragout volumes is included for three types of parts. The only specification required relative to the purity of a rinse is the maximum allowable concentration of contaminant. This concentration has not yet been established for each rinse, but an attempt to establish a value will be made in each case.

Rinsing may be defined as that process by which adherent materials are removed from the surfaces of fixtures and parts by dilution with a suitable volume of solvent. This includes spraying as well as total immersion. The spontaneous reaction occurring during an immersion of a part carrying a quantity of some solute is termed diffusion. Diffusion is simply the movement of a solute in the direction of lesser concentration. Diffusion proceeds until an equal concentration exists at every point within solution; this latter condition is called equilibrium. Among the conditions which promote more rapid diffusion are higher temperature; turbulent fluid movement; and dragging part through solution.

Diffusion rate diminishes in a non-turbulent solution as the process of mixing the solute and solvent continues. The reason for this decreased diffusion rate in a non-turbulent solution is that the rate decreases as the difference in concentration between given points decreases; this condition exists in non-flowing or non-turbulent solutions. In the case of parts having enclosures with internal and small passageways to the exterior, diffusion is relatively slow since it occurs only in one or two directions. Immersion for an extended period of time in addition to solution agitation will provide the necessary rinsing. The condition which could arise in the case of small "dead end" holes where air separates rinse water from entrapped solution is sometimes overlooked. Usually repeated dippings into rinse tank will help to remedy this difficulty. No guaranty can be made as to how well the hole of a particular part is rinsed when this condition exists.

## A. Why Rinse

Any solid part whose surface is capable of being wetted by a liquid will not drain free of that liquid even after suspending the part for an extended period of time. Furthermore, most parts will have recesses which will trap liquids and retain them during the draining period.

This adherent liquid may be undesirable for various reasons, depending on the particular series of processes that follow. However, in plating sequences, two general categories of detrimental effects can result from adherent liquids:

1. Contamination of next solution in which part is immersed, and
2. Detrimental surface residue and attack by solution adhering to part if that part is allowed to dry.

If a part is allowed to dry after a pre-cleaning sequence and before plating the final rinse solvent adhering to the part must be rendered as free from detrimental solutes as possible. The same precaution applies to final cleaning and drying of a plated part. It should be realized that if this highly concentrated contaminate or solute is not removed from the surface of a piece part and then the piece is allowed to go to dryness, this new surface condition containing adherent materials will effect all forthcoming processes or conditions that this part will experience.

Since water rinsing is the only practical process by which concentration of adherent solution can be adequately reduced without introducing other solutes, it is the process generally employed for this purpose.

## B. Rinsing Methods

A series of rinse tanks having corrosion resistant liners usually constitute the major fixtures of a rinsing installation. Water is invariably the solvent employed for rinses in plating sequences. Obviously, the water used must be of requisite purity; if not, the water supply should be treated by such methods as deionization and filtration. Each tank may have a separate pure water source. Very often the economical cascade system is employed where two or more rinses are in series. When the effluent from the higher purity rinse tanks runs into the lower purity rinse tank a considerable saving in water is achieved.

Another rinsing technique involves the use of a spray rinse. Since water flows only during actual rinsing operation, a considerable saving in water is realized. The spray rinse should not be used without a following immersion rinse because the spray rinse does not assure rinsing of all surfaces. A spray rinse followed by two immersion (cascading) rinses is one of the best rinse systems obtainable for the amount of water used.

Agitation in a rinse tank is a very important consideration in an evaluation of rinsing practices. The most common methods of water circulation within a rinse tank include; air agitation, mechanical circulation, and the proper application of input water so that maximum mixing and rinsing is acquired. Air and mechanical agitation are quite effective; they are not utilized nearly as often as relying on mixing resulting from the water input flow pattern. The tanks used for rinsing during this program employed the water input flow pattern because of its common use and efficient means of attaining adequate mixing and rinsing. For this type of rinsing the input water should be at the bottom of the tank so that there is a flow pattern of water from the bottom of the tank to the top. For the most efficient draining, the water outlet should be at the top of the rinse tank and should overflow across a wide surface area into an outlet system. There are three points that should be considered here; they are:

1. If possible, the input water should first go through a manifold which evenly distributes the water throughout the bottom of the tank. This may only have to be a pipe or tube extended across the bottom of the tank with many holes in it.
2. The overflow or drain pattern should not be through a single hole, but it should drain over as large an area as possible for most efficient draining and rinsing to complete the proper flow pattern and skim off contaminants concentrated on the rinse surface.
3. It should be recognized that for the above rinsing practice the following occurs: Upon initial entry of a set of contaminated parts into a rinse tank, the solution in the top most area of that tank becomes most contaminated. It is also this same portion of solvent or rinse water that is immediately overflowed (per the described rinse set up) and drained off, keeping the over-all concentration of contaminate within the rinse solution at a minimum.

Air agitation of rinses during immersion period markedly hastens diffusion and hence the attainment of equilibrium. Injection of water at bottom of the tank will insure more rapid removal of contaminants from an overflowing rinse tank.

Adequate drying practices are often overlooked. The degree of drying required for piece parts being processed is usually dependent on the nature and quality of work. There are two basic techniques of drying followed throughout the industry. The first is to final rinse the parts in a clean water rinse which is followed by a hot air dry. This can either be done in a hot air oven or in a circulating air chamber. The second method of drying is to use a water solvent rinse before drying to accelerate evaporation, decrease oxidation, and contamination and thereby increase, in many cases, the quality of the part. The water solvent most often used is isopropylalcohol and usually concludes a plating operation as a three rinse sequence with a hot air dry. The latter drying procedure is suggested for all work to be done under this program. It should be noted that the air exposed to the part during the drying period must be low in water content to allow more rapid drying of residue water. During the drying of residual water the concentration of any non-volatile solute present will increase until the water vapor pressure of adherent solution is the same as that for the air to which it is exposed. At this point drying ceases, and a relatively high concentration of the solute contacts the part surface. The extent of attack by this solution is ordinarily determined by the total quantity of solute per unit surface area.

#### Symbol Definitions:

$C_d$	Concentration of solution dragged into rinse (usually oz/gal).
$C_t$	Contaminant concentration in rinse at time (t) after immersion in minutes.
$C_e$	Equilibrium concentration attained in full, but non-flowing rinse tank by a single immersion.
$C_{max}$	Maximum allowable concentration in rinse tank.
$t$	Time from immersion of parts in minutes.
$s'$	Total drag-in volume into rinse per immersion in gallons.
$\ln$	Natural logarithm (math tables) of value of expression following.



F Flow rate in gal/min.

T Time interval between rinses.

### Single Rinse (Non-Running)

This type of rinse is not recommended unless the frequency of water replacement is pre-established. A continual build-up of concentration results with use.

$$C_t = \frac{s' \times C_d}{V}$$

s' Volume of solution having concentration ( $C_d$ ) which is dragged into rinse.

V Volume of rinse solution.

$C_t$  Concentration in rinse.

When ( $C_t$ ) exceeds maximum allowable concentration rinse solvent must be replaced.

### Single Rinse (Running)

The reason for running water continuously into a rinse tank is to prevent a concentration build-up in the rinse solvent. The flow rate necessary to achieve this depends on drag-in volumes ( $s'$ ) per rinsing operation, drag-in concentration ( $C_d$ ), volume of rinse tank ( $V$ ), time interval between rinsing ( $T$ ), and maximum allowable concentrate ( $C_{max}$ ). An explicit formula based on the assumption of instantaneous mixing exists:

$$\text{Flow Rate (F)} = \frac{V}{T} \ln \left[ \frac{C_{max}}{C_{max} - \frac{s' \times C_d}{V}} \right] \quad \text{Where } \frac{s' \times C_d}{V} = C_e$$

Note: The approximation that the drag-in volume does not contribute to the rinse volume has been made.

The same expression may be written in the form:

$$L = \frac{V}{F} = TX \left[ \frac{C_{max}}{C_{max} - C_e} \right]$$

The foregoing expression forms the basis for the procedure of determining the required flow rate. (L) is simply the time required to fill an empty rinse tank when flow is properly adjusted. The expression:

$$\left[ \frac{1}{\ln \left[ \frac{C_{\max}}{C_{\max} - C_e} \right]} \right]$$

called the "G" factor is plotted against  $(C_e/C_{\max})$  for convenience. All that is required for the determination of the flow rate or (L) is  $(C_e/C_{\max})$  and the time interval (T) between rinsings ( $L = TG$ ).

Procedure Recommended for Determining Flow Rate  
in Running Rinse Tank:

Step I

Measure the volume of cleaning solution adhering to parts and basket after 15 seconds of draining. This is easily accomplished by weighing wet and dry basket, with and without part load, respectively and subtracting to obtain liquid weight. Liquid volume is simply Liquid Weight/Density. The table listing drag-out volumes for various part configurations may be applied, but one must be aware of the effect of the draining method as well as the basket configuration on drag-out volume.

$$\text{Vol (gal)} = \frac{\text{Weight in Oz}}{(\text{Density in oz/gal})}$$

Step II

Calculate the concentration ( $C_e$ ) attained in the full but non-flowing rinse tank by a single immersion as follows:

1. Look up or determine concentration of cleaning solution ( $C_d$ ) in oz/gal.
2. Multiply ( $C_d$ ) by volume of drag-out ( $s'$ ) ie:  $(C_d) \times (s')$ .
3. Divide results in (2) by volume (V) of rinse tank to obtain ( $C_e$ ).

$$C_e = \frac{C_d s'}{V}$$

$C_d$  Concentration of cleaning solution (oz/gal)  
 $s'$  Volume of (gal) drag-in per immersion  
 $V$  Volume of rinse tank (gal/)

### Step III

Specify an acceptable maximum concentration ( $C_{\max}$ ) for rinse tank. If ( $C_{\max}$ ) is less than ( $C_e$ ), subsequent rinse(s) will be necessary. Also specify the time interval between rinses in the same rinse tank.

### Step IV

Divide ( $C_e$ ) by ( $C_{\max}$ ). Find value of ( $C_e/C_{\max}$ ) on Graph 1.

Read value of "G." Multiply "G" by time interval between rinsings to obtain the time necessary to fill a rinse tank when flow is adjusted properly.

Result: Flow rate is proper when tank is filled in ( $L = TG$ ) minutes.

Example:

Let:  $s' = 0.005$  Gallons  
 $C_d = 4$  (oz)/gal  
 $V = 5$  gal  
 $T = 2$  min

Specify:

$$\begin{aligned}
 C_{\max} &= 0.01 \text{ oz/gal} \\
 C_e &= \frac{C_d s'}{V} = \frac{4 \times .005}{5} = .004 \text{ oz/gal} \\
 C_e/C_{\max} &= .4 \\
 G &= 1.9 \\
 L &= G \times T \quad (L = 3.8 \text{ minutes to fill tank})
 \end{aligned}$$

### Water Drag-out Test Results

Basket: 6" Dia. x 6" High Wire Mesh

Rods: 1" long x .09375 diameter with and without holes.

Part Selection: There were two objectives in the selection of parts for testing rinsing practices. The first being that the parts should have the configuration of contacts due to the purpose of this program. Second, the parts should be of three different configurations in order that we may evaluate low, medium, and high drag-out rates.

Part #1: Pin contacts with no holes.

Part #2: Pin contacts with holes.

Part #3: Miscellaneous parts selected for high drag-out.

Each value is averaged from three or more readings.

Note: For Parts: Unit is in gallons/1000 square feet.  
For Basket: Unit is gallons.

15 SECOND DRAIN			30 SECOND DRAIN		
	Basket Not Tilted	Basket Tilted 45°		Basket Not Tilted	Basket Tilted 45°
Basket	.00485	.0030	Basket	.00436	.0026
Part #1	4.7	1.3	Part #1	3.3	1.8
Part #2	5.6	1.6	Part #2	5.9	1.5
Part #3	5.6	4.0	Part #3	4.5	4.0

(Estimated Possible Error +/- 5% of Value)

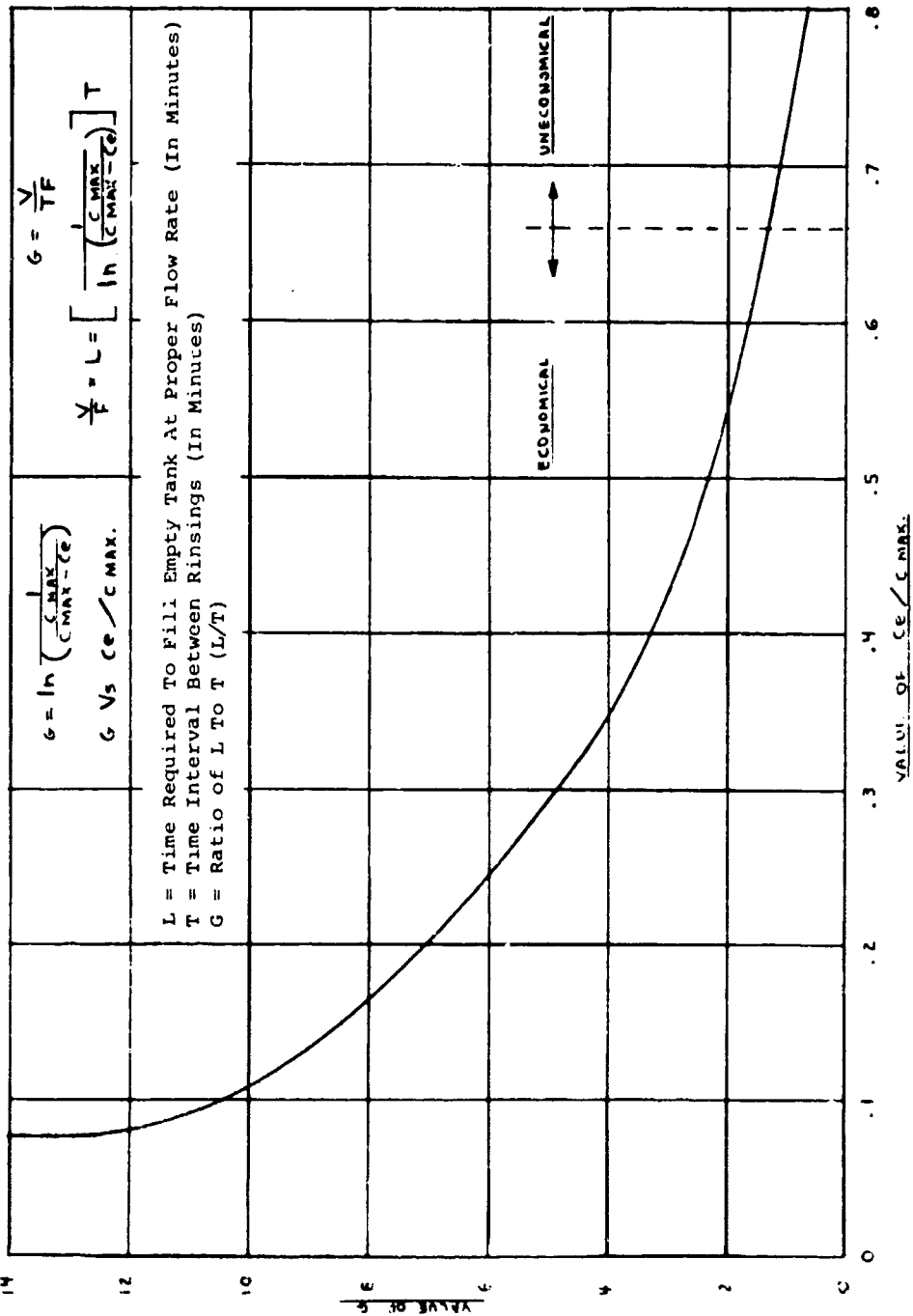
Basket with 500 parts (no hole) 15 sec. drain (tilted) .0044 gal  
Basket with 500 parts (with holes) 15 sec. drain (tilted) .0049 gal

It should be recognized that in addition to the configuration of the part, and orientation during draining, drag-out depends on the composition and temperature of the solution. The above data illustrates the average of tilting the basket. By tilting the basket one renders a vertical component to the axis of the cylindrical parts which promotes more complete draining. No substantial reduction in drag-out after draining for 15 seconds was observed.

GRAPH I

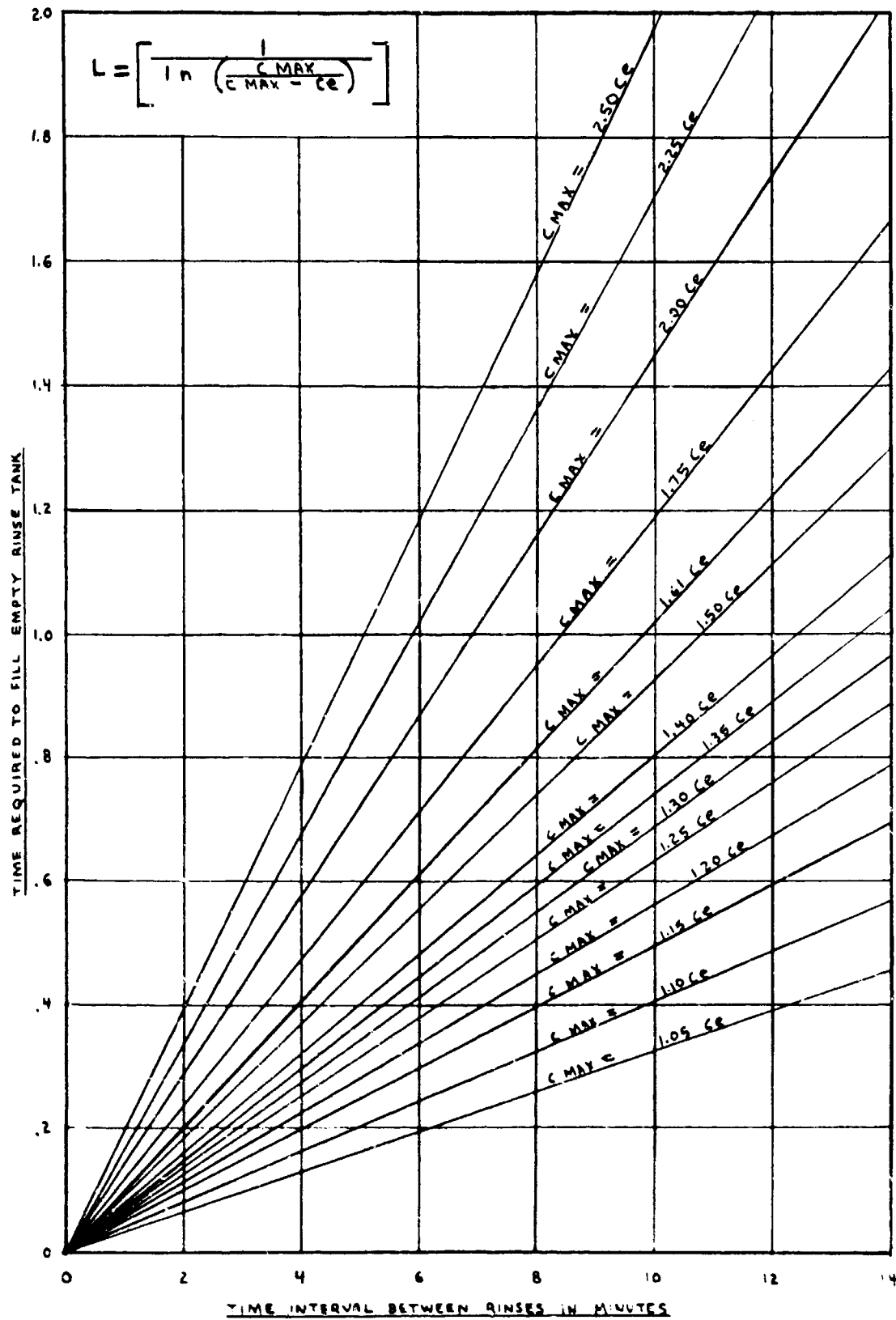
RINSE TANK FLOW RATE (DETERMINATION)

NOTE: WHEN  $G$  IS LESS THAN (1),  $L$  IS LESS THAN  $T$ ; IN THIS CASE, ONE COULD FILL THE EMPTY TANK WITHIN THE INTERVAL BETWEEN RINSINGS. SUCH A HIGH FLOW RATE WOULD BE UNECONOMICAL.



GRAPH 2

RINSE TANK FLOW RATE (DETERMINATION)



#### Solution Drag-outs - Tables VI and VII

Some measurements of drag-out from a few (acid) clean solutions were taken with parts #1 and #2. The results are to be used only as a rough estimation of the drag-outs that can be expected with similar solutions. It is evident that viscous solutions such as those containing substantial quantities of sulfuric acid provide high drag-out weights. It is also clear that a 15 second drain is adequate in each case. In interpreting the data of Tables VI and VII, one must not overlook the fact that different quantities of parts were involved in the two tables; also drag-out weights rather than drag-out volumes are recorded.

#### Flow Dilution Measurements - Graphs 3 and 4

In order to confirm the validity of the assumption of instantaneous mixing, the acid concentration of a five gallon running (1.5 gal/min) rinse tank was measured at various time intervals after immersion of parts covered with an acid clean solution. The concentration measured at 10 seconds was taken as the initial equilibrium concentration ( $C_i$ ). The results provide no reason to doubt the validity of the above assumption.

TABLE NO. VI  
SOLUTION DRAGOUT  
EXPERIMENTAL RESULTS  
PART NO. 1 (WITHOUT HOLES)

TIME	AMMONIUM PERSULFATE	FLUOBORIC ACID	SULFURIC ACID	HYDROCHLORIC ACID	POTASSIUM CYANIDE	ALKALINE SOAP CLEANER
5 SEC.	25 g	21 g	28 g	22 g	21 g	6 g
10 SEC.	17 g	18 g	21 g	18 g	17 g	5 g
15 SEC.	15 g	17 g	20 g	17 g	17 g	5 g
30 SEC.	14 g	16 g	19 g	16 g	15 g	

SOLUTION DRAGOUT IN GRAMS

EACH TEST INCLUDED A 6" X 6" WIRE MESH BASKET AND 485 PARTS

BASKET WIRE MESH SIZE = 10 OPENINGS PER INCH

TABLE NO. VII  
SOLUTION DRAGOUT  
EXPERIMENTAL RESULTS  
ART NO. 2 (WITH HOLES)

TIME	AMMONIUM PERSULFATE	FLUOBORIC ACID	SULFURIC ACID	HYDROCHLORIC ACID	POTASSIUM CYANIDE
5 SEC.	25 g	19 g	30 g	20 g	23 g
10 SEC.	19 g	16 g	20 g	15 g	18 g
15 SEC.	16 g	15 g	18 g	14 g	18 g
30 SEC.	14 g	13 g	17 g	12 g	17 g

SOLUTION DRAGOUT IN GRAMS

EACH TEST INCLUDED A 6" X 6" WIRE MESH BASKET AND 430 PIECES

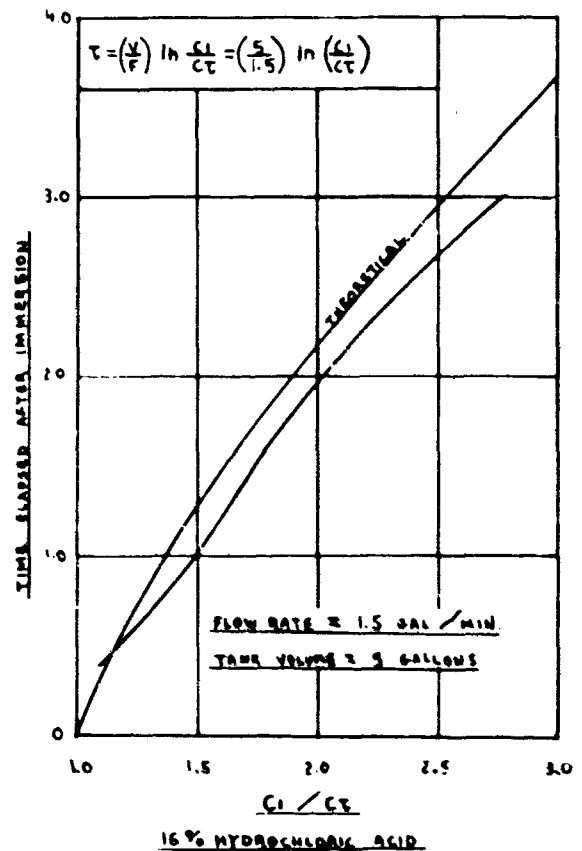
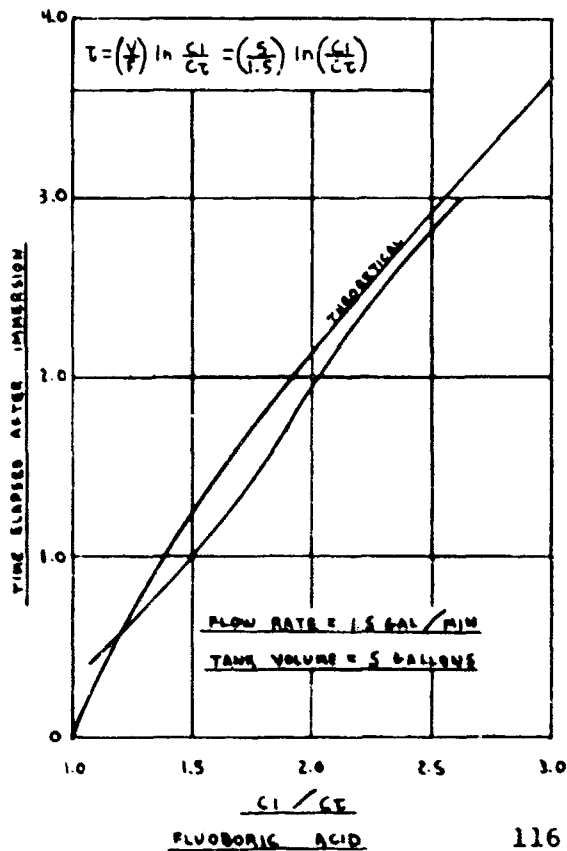
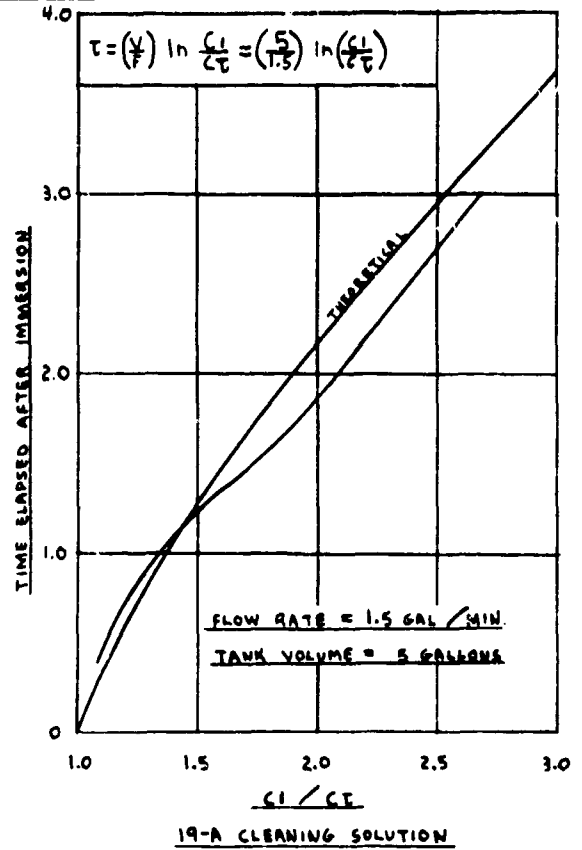
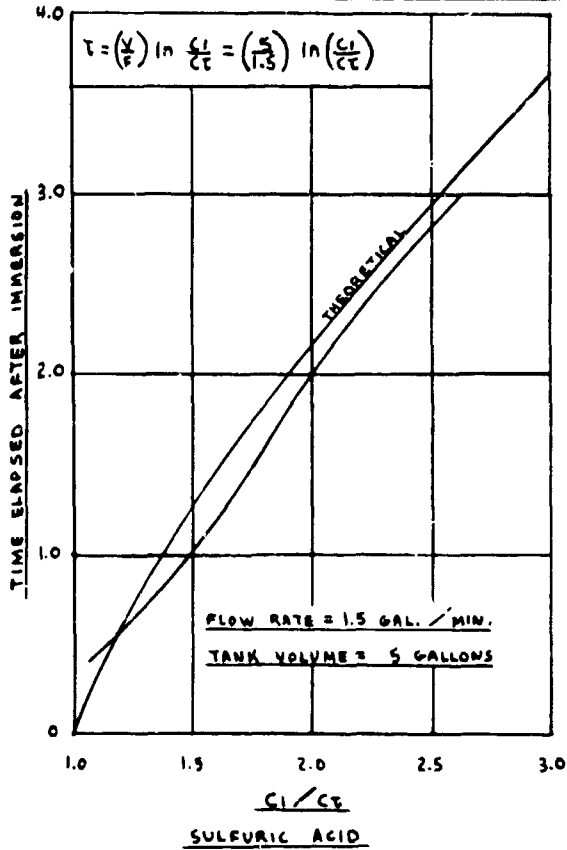
BASKET WIRE MESH SIZE = 10 OPENINGS PER INCH

TEST RESULTS FOR PART NO. 3 WERE INCONCLUSIVE  
DUE TO INCONSISTENT RESULTS.



GRAPH 3  
RINSE TANK CONTAMINANT MEASUREMENTS  
Part No. 1 (Without Holes)

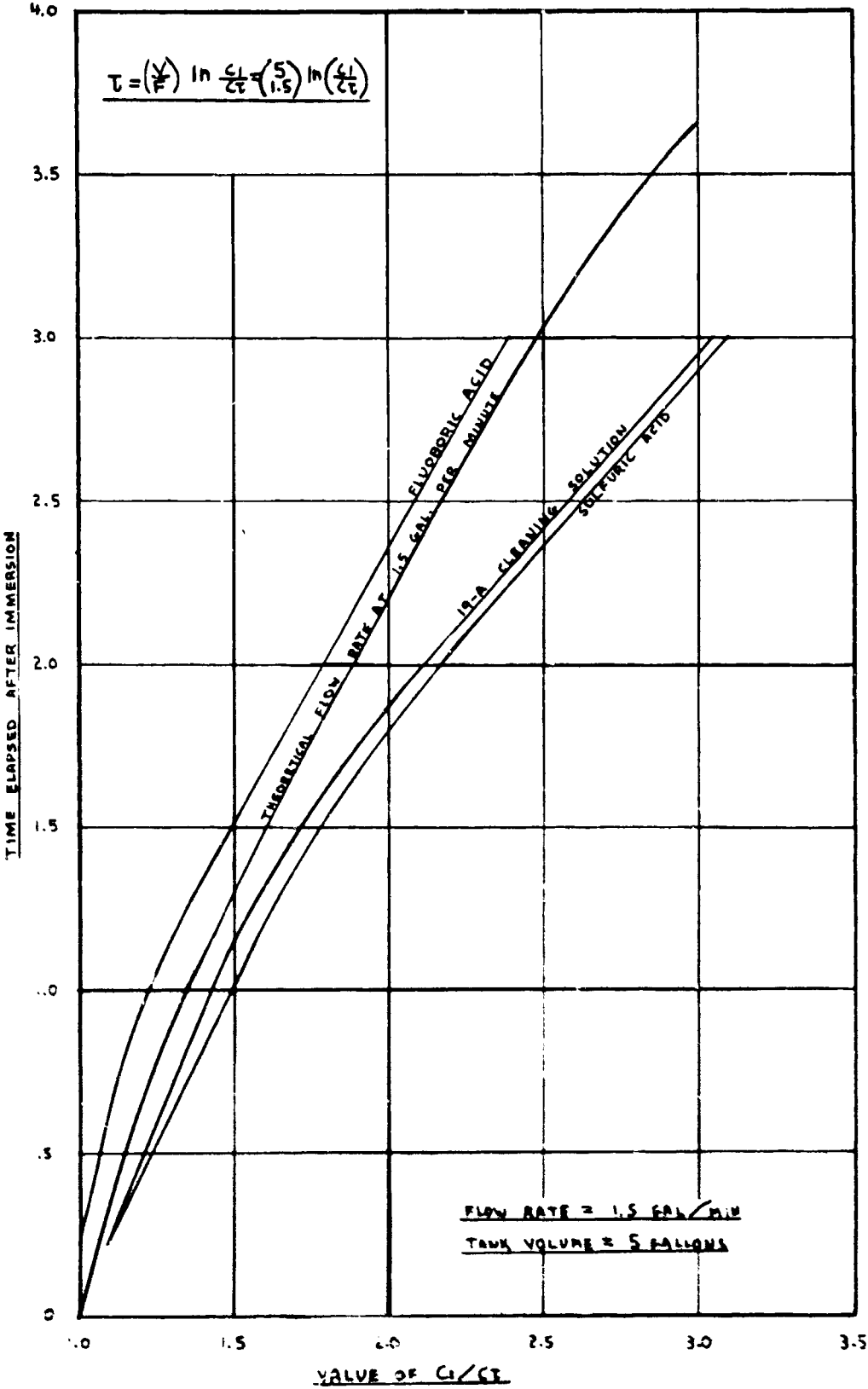
EACH GRAPH COMPARES THE PERCENT CHANGE OF THE THEORETICAL CONTAMINANT CONCENTRATION  
TO THAT OF THE EXPERIMENTALLY MEASURED CONCENTRATION



GRAPH 4

RINSE TANK CONTAMINANT MEASUREMENTS  
Part No. 2 (With Holes)

THIS GRAPH COMPARES THE PERCENT CHANGE OF THE THEORETICAL CONTAMINATE  
CONCENTRATION TO THAT OF THE EXPERIMENTALLY MEASURED CONCENTRATION



XI.

#### CRIMP EVALUATION

The objective of this section was to investigate crimping for the purpose of and to the extent that the plating standards, controls and processes being established in the over-all contract work would be consistent with requirements for contacts of the crimp type.

Ductility of the tested basis metals had a significant influence on the formation and character of the crimps. Ductility is the ability of a metal to deform plastically without fracturing. Under the pressure of the crimp tool, the contact barrel must cold flow (both radially and longitudinally) in balance with the distortion of the wire. Sufficient plasticity is mandatory so that the deformation is permanent producing a compact crimp. User Survey and test findings indicate that plasticity is one of the predominant properties effecting proper crimping.

A crimp test and evaluation was made on all of the basis metals outlined in this report except the nickel-iron alloy. The nickel-iron alloy was deleted from this test due to its poor machineability and because the User Survey found crimp usage not applicable to this material.

During this investigation it was found that the following properties effected the crimp evaluation: the crimp barrel dimensions, crimp indent, the crimp tool used, the wire or cable to which one is crimping, the electroplated layer on the surface of the crimp barrel or on the cable to which you are crimping, the ductility and tensile strength of the metal being crimped, and the temperatures to which the crimp will be subjected. All of these characteristics are known to effect crimp evaluation, however, most of these properties have already been determined and are called out in the military specifications MIL-C-26636, MIL-C-26500, MS-3191, and MIL-T-22520. The purpose here, therefore, is to further evaluate the properties of those contact basis metals listed in this report with respect to crimping.

The approach taken in investigating crimping was to test and evaluate the following characteristics: (1) a measure of the millivolt drop across the crimp for each material and hardness

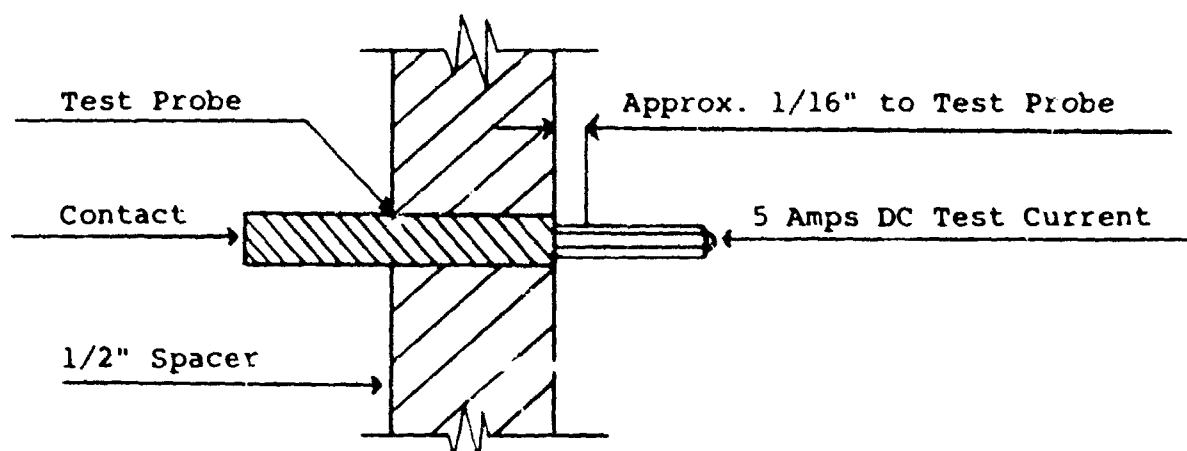
level investigated, (2) a tensile strength test of the crimp for each given material and hardness thereof, and (3) a photographic study of magnified crimp cross sections.

This section deals with results obtained from crimping tests on the seven basis metals and the relationships of these results to contact electroplating. These tests were performed and reported as characteristic checks of the basis materials and not as a study of crimp design or procedure.

This is a composite check yielding a response from a number of interrelated properties; the malleability of the contact crimp barrel being of primary importance. Successful crimping can be performed on a wide range of hardnesses if the barrel exhibits proper plastic flow; however, without suitable malleability, even metals of optimum hardness will not crimp satisfactorily. The ratings presented in this section are derived from data taken on a specific set of conditions. Variation of these conditions can alter the relative ratings of the different basis metals.

Each test sample contact was crimped to a length of #16 strand wire per MIL-W-16878. The crimping tool used meets the requirements of MIL-T-22520 specification.

The electrical resistance test consisted of the measurement of the millivolt drop across the crimp joint of each material and at each hardness level using a test current of 5 amps DC. It was first decided that the crimp joint resistance could not be measured by itself accurately, therefore, a specific section of the contact including the crimp joint was calibrated for resistance measurements. The diagram below shows the portions of the contact at which millivolt drop was measured:



That portion of the diagram labeled "spacer" was in the form of a clamp and was the means by which the contact was held firmly in position. A picture of this setup is included on page 63 of this report.

The millivolt drop readings taken for this work section are included in Table V, page 67, along with related data from other report sections for ease in comparison.

The second set of tests conducted relative to a crimp determination was to make a tensile test of crimp joints on all the listed materials at three hardness levels of each material with the exception of the beryllium copper and nickel-iron alloy. This test was performed on a Dillon Tensile Tester using a 0-250 pound dynamometer. The rate of pull used during this test was two inches per minute.

The third part of this work involved making metallurgical mounts (cross sections) of crimp joints and photographing representative samples of each metal for each condition. All photographs are at 25 power.

The millivolt drop data reveals a definite pattern in the values before and after temperature durability. The percent change in millivolt drop (which is a measure of joint resistance change) is consistently higher for the softer metals.

The tensile strength data shows a trend of higher values of tensile for softer metals with an indication of an optimum level per metal. Beyond this optimum further reductions of hardness start to show lower values of tensile strength.

The cross sections also indicate a nominal hardness level for the best crimp conditions. It must be understood that with these changes in hardness there can be significant changes in ductility which will simultaneously effect the crimp quality.

The hardest materials such as beryllium copper and phosphor bronze #1 excessively deformed the wire strands reducing the wire cross sectional area. These crimps show poor tensile strength.

In the case of the full hard leaded brass, there was not sufficient ductility to withstand the crimping action and fracture occurred in a high percentage of the parts. There was a slight tendency for fracture in the half hard brass also.

Quarter hard brass had sufficient ductility to respond well to the crimp action and formed well to fill the entire cavity.

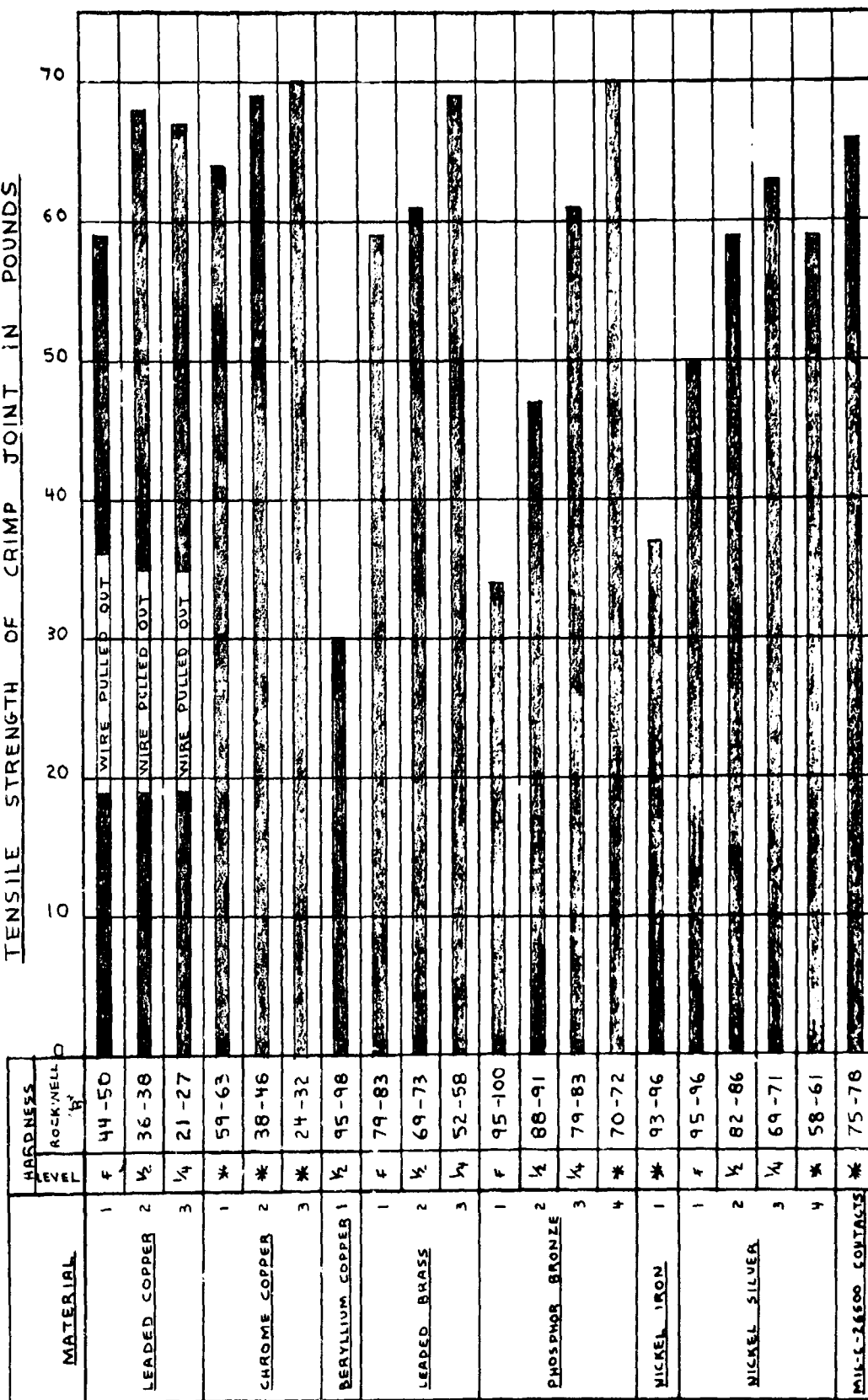
Leaded copper is at a suitable level in the full hard condition as received. The joint formed and compacted well. Half hard and quarter hard leaded copper produced joints exhibiting voids and a lack of compression of the wire strand resulting from too much yield in the barrel.

Some contacts showed gaps between the crimp barrel wall and the wire indicating a springback of the wall after crimping. This results from an elastic rather than a plastic deformation of the crimp barrel.

The following is a list of the crimp ratings of the six basis materials as compared to the procured contact per MIL-C-26636, (Procured contact rated 20).

<u>MATERIAL</u>	<u>RATING</u>
Leaded Copper #1	17
Leaded Copper #2	11
Leaded Copper #3	9
Chrome Copper #1	14
Chrome Copper #2	16
Chrome Copper #3	14
Beryllium Copper #1	4
Leaded Brass #1	0
Leaded Brass #2	15
Leaded Brass #3	19
Phosphor Bronze #1	4
Phosphor Bronze #2	8
Phosphor Bronze #3	16
Phosphor Bronze #4	19
Nickel Silver #1	4
Nickel Silver #2	11
Nickel Silver #3	15
Nickel Silver #4	11

GRAPH 5  
TENSILE STRENGTH OF CRIMP JOINT IN POUNDS



\* CHROME COPPER - ARBITRARY HARDNESS LEVELS.  
 \* NICKEL SILVER & PHOSPHOR BRONZE - LESS THAN 1/4 HARD.  
 \* NICKEL IRON - HARDNESS OF RECEIVED MATERIAL ONLY.  
 \* MIL-C-26500 CONTACTS - HARDNESS OF RECEIVED CONTACTS ONLY.  
 PULL RATE = 2 INCHES PER MINUTE  
 (Tellurium Copper Contacts)

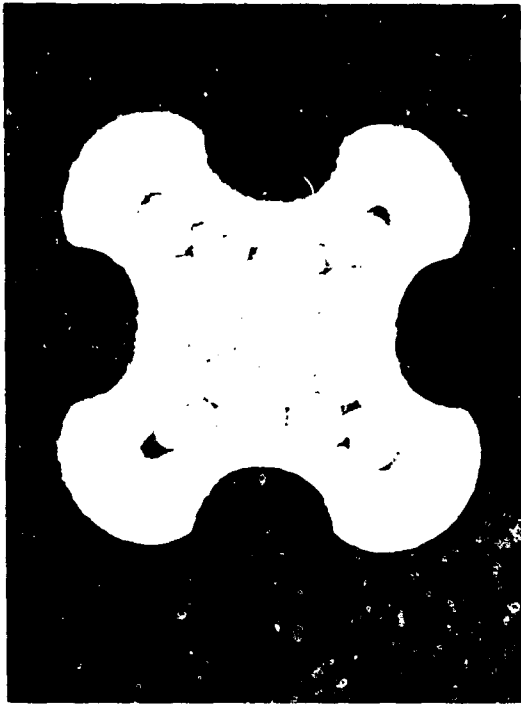
CRIMP CROSS SECTIONS

Conditions: Crimp tool per MS-3191

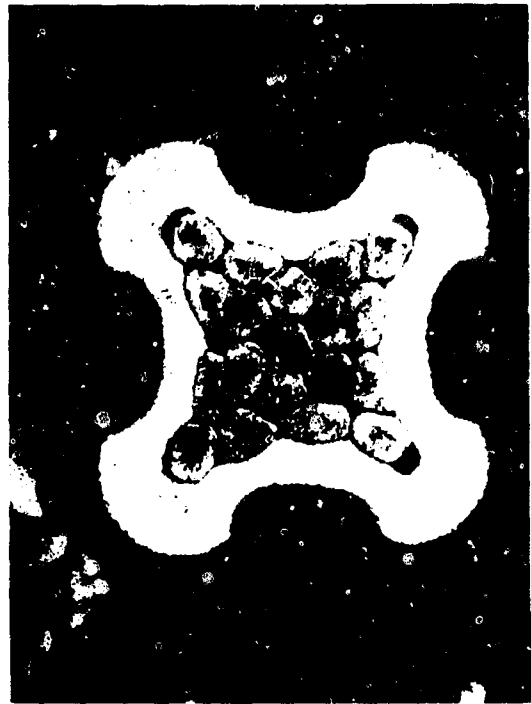
Wire per MIL-W-16878

Magnification 25X

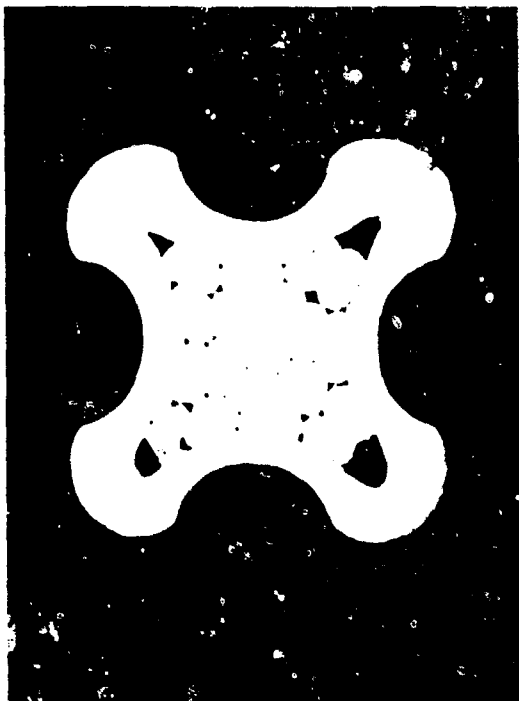
Purpose: Observe geometry and condition of crimps



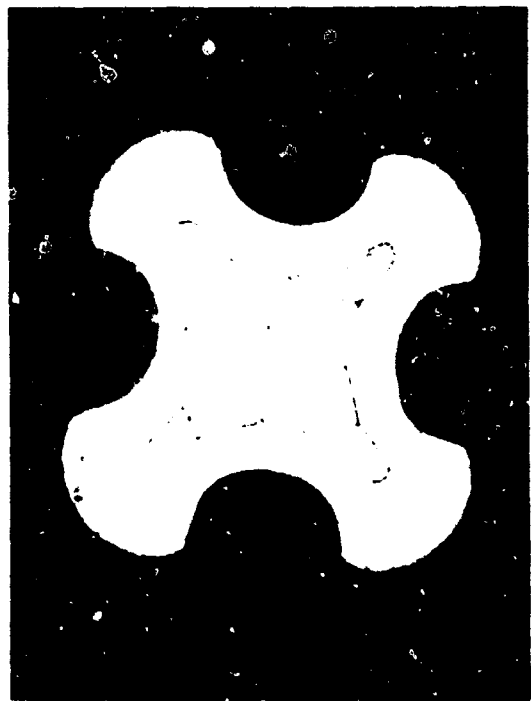
Leaded Copper #1



Leaded Copper #2



Leaded Copper #3



Procured



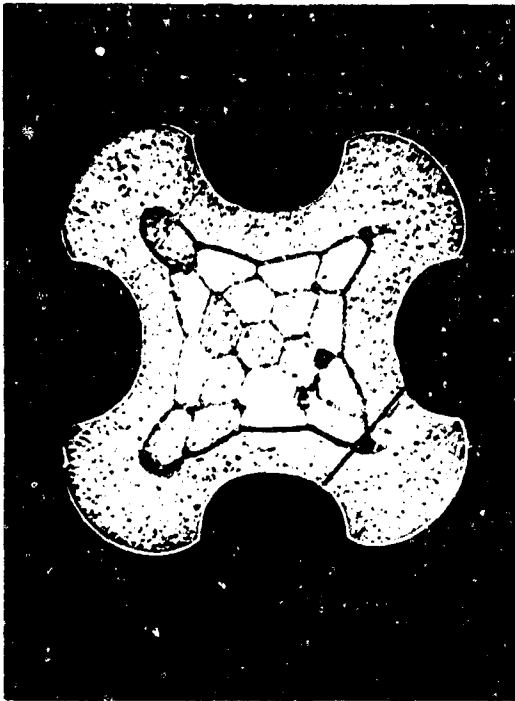
CRIMP CROSS SECTIONS

Conditions: Crimp tool per MS-3191

Wire per MIL-W-16878

Magnification 25X

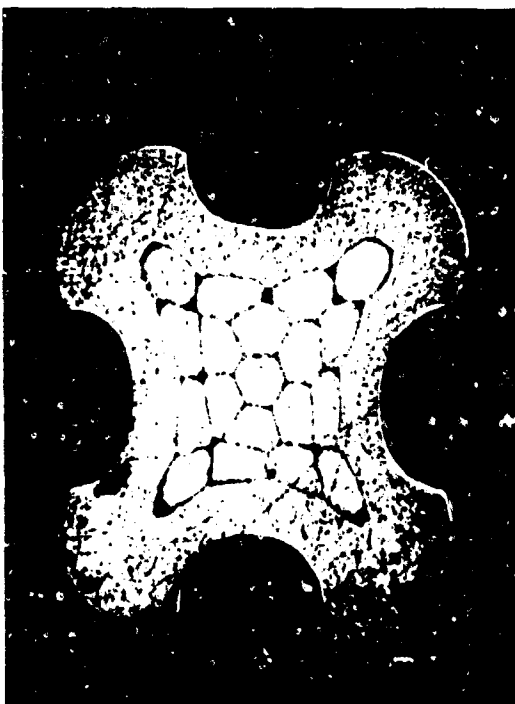
Purpose: Observe geometry and condition of crimps



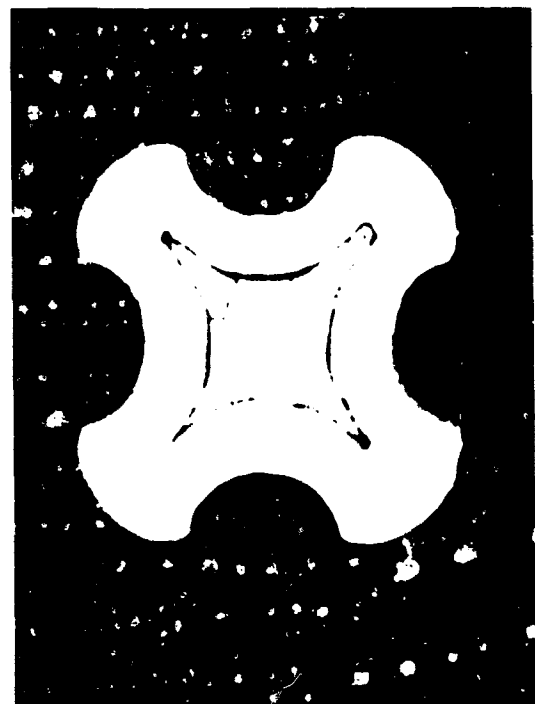
Chrome Copper #1



Chrome Copper #2



Chrome Copper #3



Beryllium Copper #1

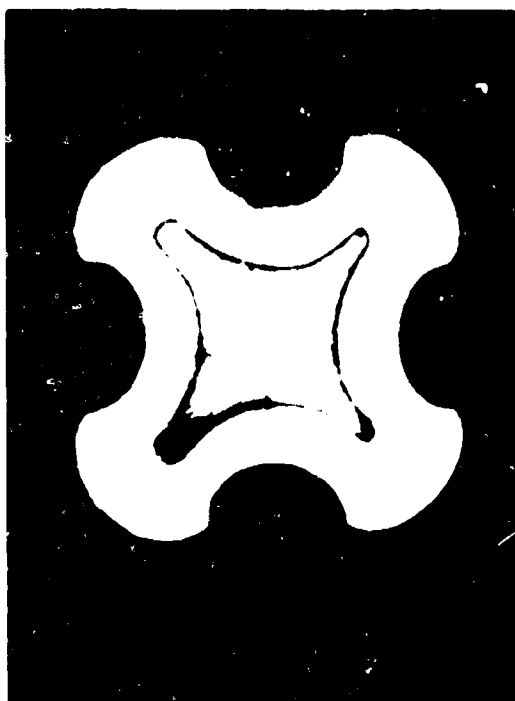
CRIMP CROSS SECTIONS

Conditions: Crimp tool per MS-3191

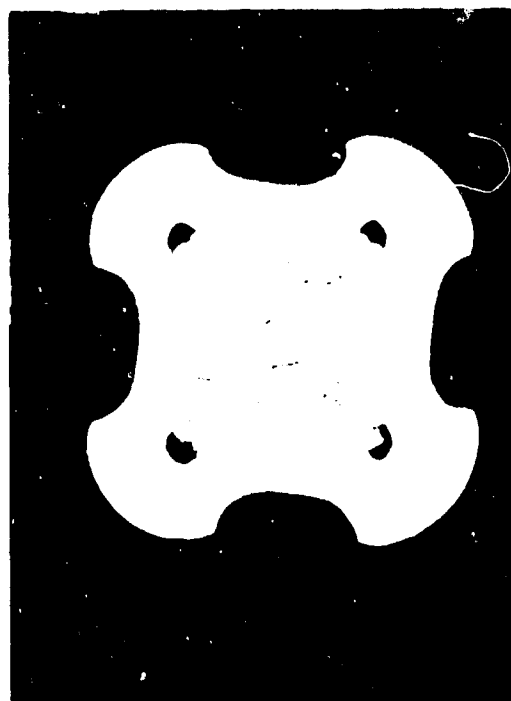
Wire per MIL-W-16878

Magnification 25X

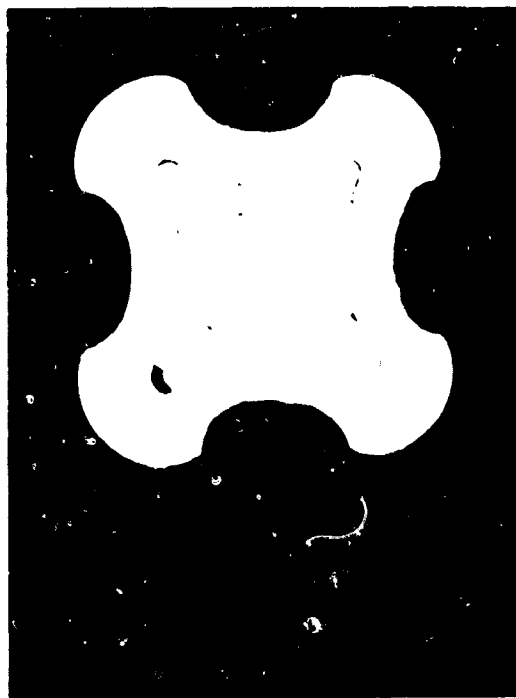
Purpose: Observe geometry and condition of crimps



Phosphor Bronze #1



Phosphor Bronze #2



Phosphor Bronze #3



Procured Contact  
per MIL-C-26500

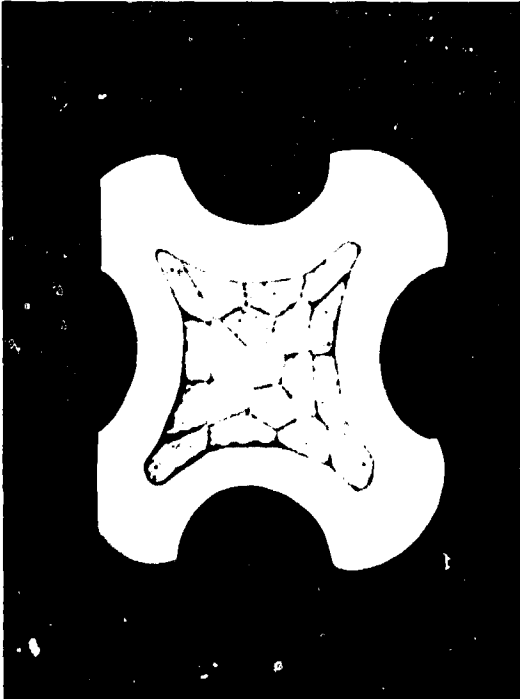
CRIMP CROSS SECTIONS

Conditions: Crimp tool per MS-3191

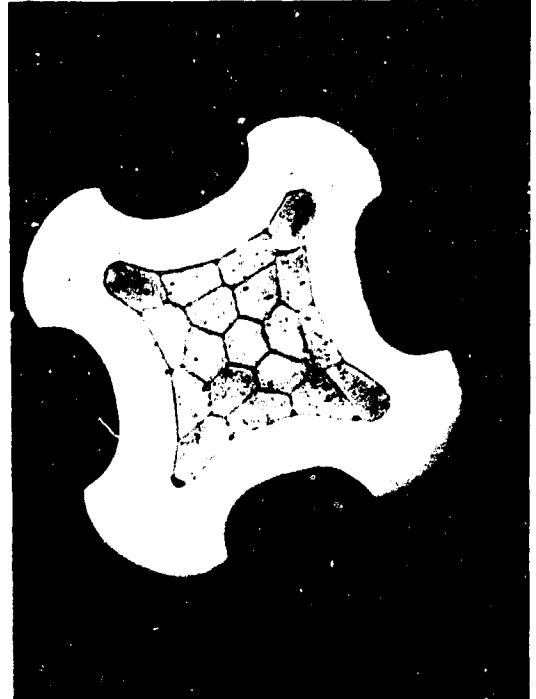
Wire per MIL-W-16878

Magnification 25X

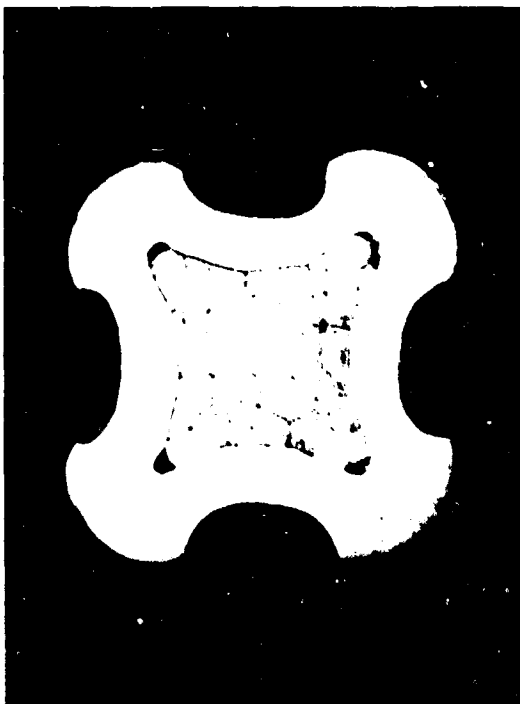
Purpose: Observe geometry and condition of crimps



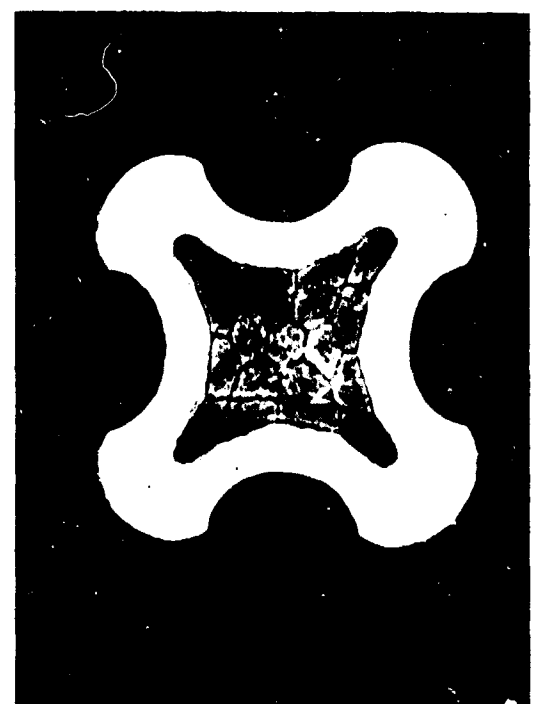
Nickel Silver #1



Nickel Silver #2



Nickel Silver #3



Nickel Silver #4

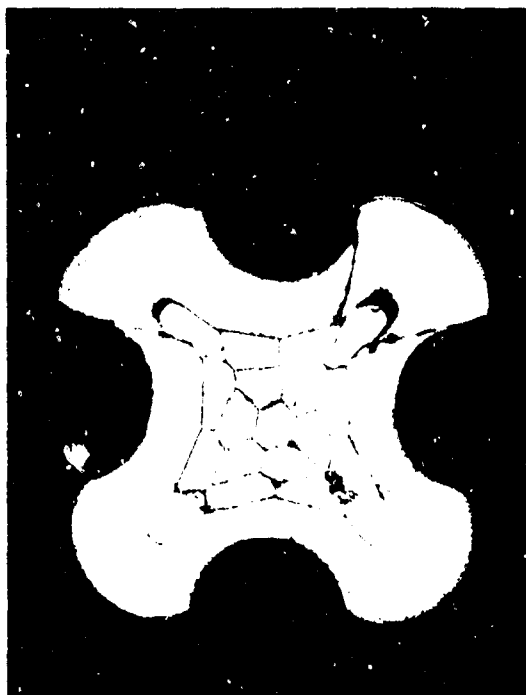
CRIMP CROSS SECTIONS

Conditions: Crimp tool per MS-3191

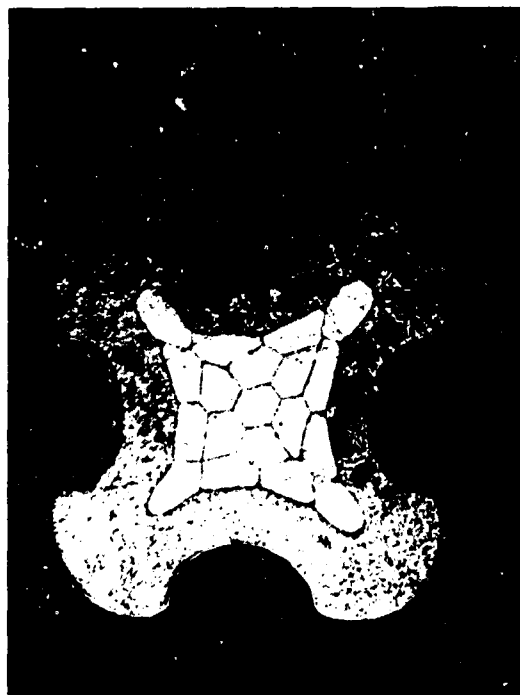
Wire per MIL-W-16878

Magnification 25X

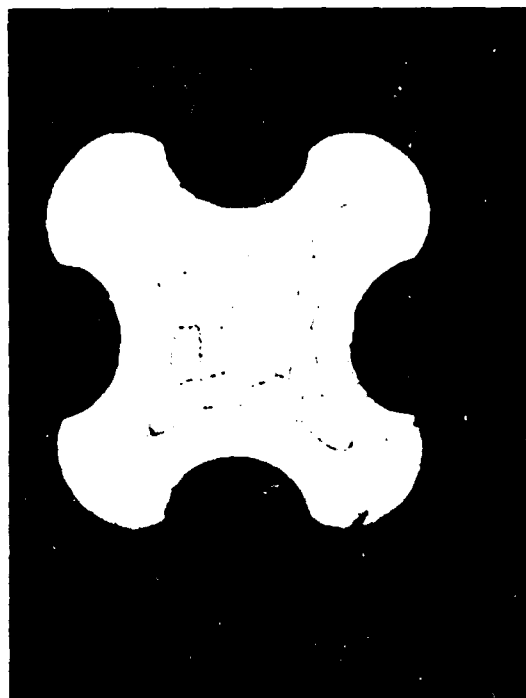
Purpose: Observe geometry and condition of crimps



Leded Brass #1



Leded Brass #2



Leded Brass #3

# XII. SCHEDULE OF PLATING PARAMETER TEST LEVELS AND PLATING SOLUTIONS EMPLOYED

CHART 1 - SCHEDULE OF PLATING PARAMETER TEST LEVELS\*

	pH Test Made		Brighteners Test Made		Temperature 20% High		Temperature Standard		Temperature 20% Low	
	Current Density 20% High	Current Density Standard	Current Density 20% High	Current Density Standard	Current Density 20% Low	Anode Area 50% High	Anode Area 50% Low	Anode Area 50% High	Anode Area 50% Low	Anode Area 50% Low
Bath Concentration - 20% High	X	X	X	X	X	-	-	-	-	-
Bath Concentration - 10% High	X	X	X	X	X	-	-	-	-	-
Bath Concentration - Standard	X	X	X	X	X	X	X	X	X	X
Bath Concentration - 10% Low	X	X	X	X	X	-	-	-	-	-
Bath Concentration - 20% Low	X	X	X	X	X	-	-	-	-	-
Current Density - 20% High	-	-	-	-	-	-	-	-	-	-
Current Density - Standard	-	-	-	-	-	X	X	X	X	X
Current Density - 20% Low	-	-	-	-	-	-	-	-	-	-
Anode Area - 50% High	X	X	X	X	X	-	-	-	-	-
Anode Area - Standard	X	X	X	X	X	X	X	X	X	X
Anode Area - 50% Low	X	X	X	X	X	-	-	-	-	-
Temperature - 20% High	X	X	X	X	X	-	-	-	-	-
Temperature - Standard	X	X	X	X	X	X	X	X	X	X
Temperature - 20% Low	X	X	X	X	X	-	-	-	-	-

The above is an outline designed to show the parameters of plating tested and the combinations thereof. This series of plating tests was conducted for all twelve plating baths that were evaluated herein. There were hundreds of plating tests incorporated within this contract work, each one being different from the other. Due to the nature of this work it was not applicable to evaluate brighteners, anode area, and temperature against the different levels of bath concentration.

\*During the progress of this contract work engineering evaluations proved that tests conducted using parameter levels below that recommended by the supplier gave less than acceptable results. Therefore, these tests were periodically deleted.

CHART 2

ELECTROPLATING TEST SCHEDULE

	<u>Tin</u> <u>Nickel</u>	<u>Nickel</u>	<u>Rhodium</u>	<u>HG Gold</u>	<u>Orosene</u> <u>Gold</u>	<u>Orotemp</u> <u>Gold</u>
	Metal Finishing Handbook	Hanson Munning Van Winkle	Technic Inc.	Technic Inc.	Technic Inc.	Technic Inc.
<u>Distributor</u>						
<u>Current Density</u>						
Recommended Standard	10.0 ASF	10.0 ASF	8.0 ASF	1.75 ASF	4.0 ASF	1.75 ASF
20% Above Recommended Standard	12.0 ASF	12.0 ASF	9.6 ASF	2.10 ASF	4.8 ASF	2.10 ASF
20% Below Recommended Standard	8.0 ASF	8.0 ASF	6.4 ASF	1.40 ASF	3.2 ASF	1.40 ASF
Special	5.0 ASF				PR9.0 ASF	
	3.0 ASF					
<u>Bath Concentration</u>						
Recommended Standard	X	X	X	X	X	X
20% Below Recommended Standard	X	-	-	X	X	-
10% Above Recommended Standard	-	X	-	X	X	X
20% Above Recommended Standard	X	X	-	X	X	X
Special Concentration	-	-	X	-	-	-
<u>Temperature</u>						
Recommended Standard	150°F	120°F	120°F	95°F	Room	145°F
<u>Anode to Cathode Ratio</u>						
Standard	4 to 1	4 to 1	1 to 1	2 to 1	2 to 1	1 to 1
50% Above Recommended Standard				3 to 1		

X Signifies plating tests were conducted at this level.

CHART 2

ELECTROPLATING TEST SCHEDULE

<u>Distributor</u>	<u>Silver</u>		<u>Bright Gold</u>		<u>Autronex N Gold</u>		<u>Autronex C Gold</u>		<u>Autronex CI Gold</u>		<u>Temperex S Gold</u>	
	Lea	Ronal Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.	Sel-Rex Inc.
<u>Current Density</u>												
Recommended Standard	5.0 ASF		3.0 ASF		3.0 ASF		3.0 ASF		3.0 ASF		3.0 ASF	
20% Above Recommended Standard	6.0 ASF		3.6 ASF		3.6 ASF		3.6 ASF		3.6 ASF		3.6 ASF	
20% Below Recommended Standard	4.0 ASF				2.4 ASF							
Special	PR16.0 ASF											
<u>Bath Concentration</u>												
Recommended Standard	X		X		X		X		X		X	
20% Below Recommended Standard	-		X		-		-		-		-	
10% Above Recommended Standard	X		-		-		-		-		-	
20% Above Recommended Standard	X		X		X		X		X		X	
<u>Temperature</u>												
Recommended Standard	Room		Room		95°F		95°F		95°F		120°F	
<u>Anode to Cathode Ratio</u>												
Standard	4 to 1		5 to 1		4 to 1		4 to 1		4 to 1		4 to 1	
50% Above Recommended Standard					6 to 1							

X Signifies plating tests were conducted at this level.

#### A. Quality Assurance Rating System for Plating Tests

The following is a description of how test plating lots were evaluated and rated as shown in the tables of this report.

##### Porosity -- 0 to 10 Points

Ten points being allotted to a test showing no porosity and 9 through 0 points assigned to different degrees of porosity. In other words, the more positive the test for porosity is the least number of points will be given for that test.

##### Microfinish -- 0 to 5 Points

Five points being allotted to a surface finish that had been improved over the basis metal finish by  $\sqrt{4}$  or more microinches.

Four points for a surface finish that was improved over the basis metal finish by  $\sqrt{3}$  microinches.

Three points for a surface finish that was improved over the basis metal finish by  $\sqrt{2}$  microinches.

Two points for a surface finish that was improved over the basis metal finish by  $\sqrt{1}$  or  $\sqrt{1}$  microinch.

One point for a surface finish that was impaired by  $\sqrt{1}$  or  $\sqrt{2}$  microinches.

##### Appearance -- 0 to 3 Points

Zero points means poor appearance upon visual inspection. This includes dark color, grain like surface, flaking, peeling, poor throwing power, etc.

One Point usually meant that the appearance was good except for color. This would include slight darkening.

Two points would be given an electroplated layer that visually was ranked good.

Three points is considered excellent. This included high luster and good adhesion.



B. QUALITY ASSURANCE TESTS CONDUCTED ON OROTEMP GOLD PLATING

SAMPLE PAGE  
PLATING TEST DATA

Test	Bath Parameters	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Plating Thickness	Average Ratings	
										Micro Porosity	Visual Final
1	C/D 20% L B/C 10% L Others-Std	3.0	9.1	0.8	3.0	2.3	3.5	9.8	.000075"	1	4.5 1 6.5
2	C/D 20% L B/T 20% H Others-Std	4.6	10.0	3.5	7.3	5.5	8.0	10.0	.000060"	2	7.0 3 12.0
3	C/D 20% H B/T 20% L Others-Std	6.7	10.0	7.0	5.5	10.0	7.6	10.0	.000053"	2	8.1 1 11.1
4	C/D 20% H Anode 50% H Others-Std	0.0	10.0	8.3	5.8	2.3	7.6	10.0	.000049"	2	6.3 2 10.3
5	C/D 20% H Anode 50% L Others-Std	1.8	10.0	7.4	10.0	2.0	10.0	10.0	.000051"	3	7.3 1 11.3
6	C/D 20% H B/C 10% H Others-Std	7.0	10.0	10.0	10.0	10.0	9.6	10.0	.000090"	1	9.6 3 13.6
7	B/T 20% H Others-Std	7.6	10.0	4.1	5.0	3.0	10.0	10.0	.000088"	2	7.1 1 10.1
8	C/D 20% H B/C 20% H Others-Std	9.1	10.0	9.6	10.0	6.7	10.0	10.0	.000111"	1	9.3 2 12.3
9	C/D 20% H B/C 10% L Others-Std	5.5	10.0	4.5	3.3	3.0	9.1	10.0	.000051"	2	6.5 1 9.5
10	All Std	10.0	10.0	9.6	10.0	8.8	10.0	10.0	.000166"	3	9.2 2 14.8

C. QUALITY ASSURANCE TESTS CONDUCTED ON AUTRONEX GOLD PLATINGS

SAMPLE PAGE  
PLATING TEST DATA

Test	Bath Parameters	Pb				Cr		Te		P	Ni	Plating Thickness	Average Ratings	
		BRS	Be Cu	Pb Cu	Cr Cu	Cu	Cu	Cu	Cu	BRZ	Ag		Micro Porosity	Visual Final
10	All Std.	P 0.6	10.0	10.0	10.0	5.5	10.0	7.0	10.0	10.0	10.0	.000060"	2.3	7.6 3 12.9
		M 4.0	3.0	2.0	1.0	2.0	-	2.0	2.0	2.0	2.0			
10R	All Std.	P 6.3	10.0	5.0	4.8	5.8	10.0	10.0	10.0	10.0	10.0	.000053"	1.7	7.4 3 12.1
		M 2.0	2.0	1.0	3.0	-	1.0	1.0	1.0	1.0	1.0			
42	All Std.	P 10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	-	.000096"	1.0	10.0 3 14.0
		M 1.0	1.0	1.0	1.0	1.0	-	1.0	-	-	-			
42R	All Std.	P 7.4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	.000094"	2.0	9.6 3 14.6
		M 4.0	2.0	2.0	1.0	1.0	-	2.0	1.0	1.0	1.0			
43	All Std.	P 10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	-	.000195"	1.2	10.0 3 14.2
		M 2.0	2.0	0.0	1.0	1.0	-	1.0	-	-	-			
88	C/D 20% H	P 7.1	10.0	10.0	10.0	10.0	10.0	7.0	10.0	10.0	10.0	.000050"	1.7	9.2 3 13.9
		M 3.0	3.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0			
91	C/D 20% H	P 6.8	10.0	3.8	10.0	10.0	10.0	7.3	10.0	10.0	10.0	.000057"	2.0	8.3 3 13.3
		M 3.0	4.0	1.0	1.0	1.0	-	2.0	1.0	1.0	1.0			
92	Anod 50% H	P 5.6	10.0	6.1	6.7	8.5	10.0	10.0	10.0	10.0	10.0	.000051"	2.3	8.1 3 13.4
		M 4.0	4.0	1.0	2.0	-	2.0	2.0	1.0	1.0	1.0			
93	C/D 20% H	P 7.3	10.0	10.0	10.0	10.0	7.6	10.0	10.0	10.0	10.0	.000056"	1.8	9.3 3 14.1
		M 3.0	3.0	1.0	1.0	1.0	-	1.0	2.0	1.0	2.0			
	Others-Std.													

TABLE VIII

PLATING SOLUTIONS EMPLOYEDA. Standard Bath Concentrations1. Silver -- Lea Ronal, Inc.

Silver Cyanide	As Metal	4.5 oz/gal
Potassium Cyanide	As Free Cyanide	10 oz/gal
Potassium Carbonate		3 oz/gal
Silver Glo 3KBP		75 ml/gal
Silver Glo TY		19 ml/gal

2. HG Gold -- Technic, Inc.

Gold HG-1 Make Up Salts	As Metal	5 dwt/gal
Gold RHG-2B Replenishing Salt	As Metal	10 dwt/gal
Potassium Phosphate Dibasic		12 oz/gal
Potassium Cyanide		0.5 oz/gal
pH 8.0 to 10.0		
Specific Gravity 10.0° to 20.0° Baume		

3. Orosene 999 -- Technic, Inc.

Orosene 999 Gold Salts	As Metal	15 dwt/gal
Orosene Make Up #1		1½ lb/gal
Orosene Make Up #2		300 ml/gal
pH 4.0 to 4.5		

4. Orotemp 24 -- Technic, Inc.

Orotemp 24 Gold Salts	As Metal	15 dwt/gal
Orotemp Additive #1		1½ lb/gal
pH 5.0 to 7.0		

5. Autronex N -- Sel-Rex, Inc.

As received from Sel-Rex, Inc.		
Gold	As Metal	1 troy oz/gal
pH 3.2 to 4.0		
Specific Gravity 8.0° to 12.0° Baume		

TABLE VIII

6. Autronex C -- Sel-Rex, Inc.

As Received from Sel-Rex, Inc.	1 troy oz/gal
Gold	
pH 3.2 to 4.0	
Specific Gravity 8.0° to 12.0° Baume	

7. Autronex CI -- Sel-Rex, Inc.

As received from Sel-Rex, Inc.	As Metal	1 troy oz/gal
Gold		
pH 3.2 to 4.0		
Specific Gravity 8.0° to 12.0° Baume		

8. Bright Gold -- Sel-Rex, Inc.

As received from Sel-Rex, Inc.	As Metal	1 troy oz/gal
Gold		10 to 12 oz/gal
Potassium Cyanide		

9. Temperex S -- Sel-Rex, Inc.

As received from Sel-Rex, Inc.	As Metal	1 troy oz/gal
Gold		
pH 4.5		
Specific Gravity 6.0° to 8.0° Baume		

10. Nickel -- Hanson-Munning-Van Winkle

Nickel Sulfate	40 oz/gal
Nickel Chloride	8 oz/gal
Boric Acid	5 oz/gal
NL-1 Addition Agent	2 oz/gal
NL-2 Addition Agent	0.3 fl oz/gal
pH 3.5 to 4.0	

11. Tin-Nickel -- Metal Finishing Guidebook

Stannous Chloride	6.5 oz/gal
Nickel Chloride	40.0 oz/gal
Ammonium Bifluoride	7.5 oz/gal
Ammonium Hydroxide	to pH 2.5

TABLE VIII

B. Strike Bath Concentrations1. Rochelle Copper

Copper Cyanide	As Metal	3 oz/gal
Potassium Cyanide	As Free Cyanide	3 oz/gal
Potassium Carbonate		4 oz/gal
Rochelle Salt		6 oz/gal
pH 12.5 to 13.0		
Temperature 130° +/- 5°F		

2. Silver Strike

Silver Cyanide	As Metal	0.45 oz/gal
Potassium Cyanide		10 oz/gal
Room Temperature		

3. Gold Strike

Potassium Gold Cyanide	As Metal	3-5 dwt/gal
Potassium Cyanide	As Free Cyanide	4 oz/gal
Dipotassium Phosphate		4 oz/gal
Potassium Carbonate		4 oz/gal
Temperature 135° +/- 5°F		

4. Nickel Strike

Nickel Chloride	(As Metal 8 oz/gal)	32 oz/gal
18°Baume Hydrochloric Acid		16 fl oz/gal
Room Temperature		

C. Special Bath Concentrations1. Rhodium -- Technic, Inc.

Rhodium Sulfate T.P.	As Metal	30 gm/gal
66°Baume C.P. Sulfuric Acid		300 ml/gal
Sodium Lauryl Sulfate		0.05 gm/gal

### XIII.

#### PLATING TESTS

- A. Discussion: The following Chart 3, pages 139 through 151, has been so designed to condense and summarise all the data obtained from plating tests throughout this contract. Each plating test contained in this chart was repeated many times throughout this program and in each phase of work to best evaluate any data obtained.

There are three factors that should be pointed out relative to this chart. First, in the Summary-Conclusion Section of this report are listed many conclusions which are derived from this chart. Second, this chart may be used to evaluate the effects of basis metal on the quality level of the plated layer, and third, you may attain and compare relative quality assurance levels of plating based on the Nu-Line test methods when comparing thicknesses of plating and one plating to another.

It should be pointed out that all figures on this chart except for the column showing the number of tests in an average figure. In the column titled "Averages," these figures are actually averages of averages. By averaging out all the tests of any particular group, we were able to eliminate those tests that gave extremely random results, and we were able to attain figures which were more compatible and easier to compare.

When reviewing or comparing one metal finish to another based on the figures shown here, you must keep in mind that the porosity test time cycle of which these figures are based was not the same for each type of metal finish. Therefore, this data is only relative based on the consideration and applied effect these different test cycle times may have on each metal finish. Reference the section of this report on porosity test method and the test cycle times shown below:

All Golds over Basis Metal	4-Minute Test Cycle Time
All Golds over Silver Plating	4-Minute Test Cycle Time
All Golds over Nickel Plating	6-Minute Test Cycle Time
Tin-Nickel over Basis Metal	5-Minute Test Cycle Time
All Rhodium Platings	4-Minute Test Cycle Time
Nickel Plating	6-Minute Test Cycle Time
Silver over Basis Metal	This was a Soak Porosity Test, and the Test Results are not comparable.

Note: The higher the number of points the better the plating or the lesser the porosity.

#### B. Effects of Basis Metal on Porosity

This chart clearly shows that the basis metal strongly effected the porosity of the plated part. Since all basis metal had a microfinish of 10 or less before plating, the porosity variation cannot be attributed to microfinish. Close observation will show that in some cases, particularly with leaded brass, the same basis metal effect carried throughout this work regardless of which metal was being plated.

It should be noted here that the initial plating test phase was one of static strip tests. This included the wire racking of twelve piece parts and plating them per the conditions outlined in Chart 1, page 129, and Chart 2, pages 130 and 131. These tests were conducted in one gallon baths and were for the purpose of future direction or possible elimination of further plating tests based on these results. That is to say for example that these tests showed continued poor results or high porosity when plating was done using low bath concentrations, thus future testing, using low bath concentrations, was kept to a minimum.

CHART NO. 3

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROSENE GOLD PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
7	2.3	10.0	8.4	6.9	7.1	8.0	10.0	7.5	.000045" to .000058"
2	5.5	10.0	8.2	10.0	7.9	8.0	10.0	8.5	.000061" to .000082"
7	8.9	10.0	8.8	8.6	9.3	10.0	9.8	9.3	.000093" to .000115"
3	9.6	10.0	9.3	10.0	9.5	10.0	10.0	9.8	.000152" to .000166"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	.000172"
3	10.0	10.0	10.0	10.0	9.3	10.0	10.0	9.9	.000185" to .000217"
Averages 7.7		10.0	9.1	9.3	8.9	9.3	9.9	9.2	.000108"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX N GOLD PLATING

9	6.2	10.0	9.0	8.8	8.5	9.6	10.0	8.9	.000045" to .000055"
5	5.3	10.0	8.8	9.1	9.3	8.7	10.0	8.7	.000056" to .000062"
6	8.9	10.0	9.4	9.6	10.0	10.0	10.0	9.7	.000090" to .000113"
3	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	.000142" to .000195"
Averages 7.6		10.0	9.3	9.4	9.5	9.6	10.0	9.3	.000080"



CHART NO. 3  
 QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
 EFFECTS OF BASE METAL AND AUTRONEX CI GOLD PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
6	5.1	9.8	10.0	8.7	8.1	9.9	10.0	8.8	.000045" to .000053"
1	3.2	10.0	10.0	5.0	4.5	7.0	10.0	7.1	.000067"
14	9.4	10.0	9.7	8.4	8.6	10.0	10.0	9.4	.000040" to .000110"
1	8.0	10.0	10.0	10.0	8.2	9.6	10.0	9.4	.000120"
3	9.4	10.0	10.0	10.0	10.0	10.0	10.0	9.9	.000137" to .000165"
Averages	7.0	9.9	9.9	8.4	7.9	9.3	10.0	8.9	.000094"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
 EFFECTS OF BASE METAL AND TEMPEREX SS GOLD PLATING

6	3.1	9.9	8.4	8.5	7.8	9.2	10.0	8.1	.000045" to .000055"
1	1.1	10.0	6.7	10.0	10.0	9.8	10.0	8.2	.000061"
16	6.9	10.0	7.4	8.0	6.9	9.7	10.0	8.4	.000090" to .000108"
2	7.5	10.0	8.7	9.0	10.0	10.0	10.0	9.3	.000151" to .000154"
Averages	4.7	9.9	7.8	8.9	8.7	9.7	10.0	8.5	.000089"

CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROTEMP GOLD PLATING

All figures are averages of quality assurance points attained by individual plating test.

No. of Tests Avg.	Average of Tests							Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	
4	1.5	10.0	6.9	6.5	6.9	6.2	10.0	.000042" to .000051"
3	6.4	10.0	9.8	9.7	7.5	10.0	10.0	.000094" to .000111"
1	6.7	10.0	10.0	10.0	6.7	10.0	10.0	.000166"
1	10.0	10.0	5.0	10.0	10.0	10.0	10.0	.000205"
1	4.4	10.0	10.0	9.1	10.0	6.5	10.0	.000285"
Averages	5.8	10.0	8.3	9.1	8.2	8.5	10.0	.000116"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX C GOLD PLATING

6	6.4	10.0	9.3	9.3	9.5	9.9	10.0	9.2	.000046" to .000055"
14	9.6	10.0	9.8	9.0	9.0	9.7	10.0	9.6	.000092" to .000110"
1	10.0	10.0	10.0	10.0	8.5	10.0	10.0	9.8	.000113"
2	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	.000155" to .000156"
1	10.0	10.0	10.0	10.0	10.0	9.8	10.0	9.9	.000204"
Averages	9.2	10.0	9.8	9.7	9.4	9.9	10.0	9.7	.000096"

CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND HARD GOLD PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
6	4.7	10.0	8.3	7.8	6.9	10.0	10.0	8.2	.000048" to .000058"
3	5.4	9.3	9.0	7.7	5.5	10.0	10.0	8.1	.000064" to .000077"
5	5.6	10.0	6.3	7.7	6.8	8.6	10.0	7.9	.000097" to .000100"
6	8.6	10.0	8.6	10.0	9.2	10.0	10.0	9.5	.000112" to .000126"
2	8.9	10.0	9.8	10.0	9.4	10.0	10.0	9.7	.000136" to .000152"
3	10.0	10.0	9.3	10.0	9.1	10.0	10.0	9.8	.000184" to .000198"
1	10.0	9.1	10.0	10.0	8.0	10.0	10.0	9.6	.000237"
Averages	7.6	9.8	8.8	9.0	7.8	9.3	10.0	9.0	.000109"

QUALITY ASSURANCE EVALUATION OF PIATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND BRIGHT GOLD PLATING

8	3.7	9.8	9.2	9.4	7.3	9.4	10.0	8.4	.000042" to .000053"
2	4.2	10.0	10.0	10.0	9.4	10.0	10.0	9.1	.000057" to .000063"
16	7.4	10.0	8.8	8.2	9.1	9.4	9.9	9.0	.000090" to .000110"
2	8.5	10.0	10.0	7.8	10.0	10.0	10.0	9.5	.000138" to .000152"
Averages	6.0	9.9	9.5	8.9	9.0	9.7	9.9	9.0	.000084"

CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND SILVER PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests							Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	
2	6.4	5.3	5.0	5.3	5.4	5.7	5.8	.000038" to .000041"
8	6.5	5.3	5.0	5.8	5.5	5.5	5.7	.000045" to .000052"
3	6.6	7.1	5.6	5.9	5.7	6.7	6.8	.000057" to .000081"
6	8.1	6.8	6.8	8.6	7.0	7.5	7.3	.000091" to .000109"
5	10.0	9.3	10.0	10.0	10.0	10.0	10.0	.000187" to .000224"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	.000284"
Averages	7.9	7.3	7.1	7.6	7.3	7.6	7.6	.000104"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND NICKEL PLATING

2	2.3	10.0	5.8	2.8	4.6	5.3	10.0	5.8	.000091" to .000094"
2	1.8	10.0	3.4	2.0	2.1	8.1	10.0	5.3	.000098" to .000104"
3	4.9	10.0	7.8	6.3	7.2	9.4	10.0	7.9	.000128" to .000143"
5	7.3	10.0	7.1	10.0	7.5	8.5	9.5	8.6	.000188" to .000214"
Averages	4.1	10.0	6.0	5.3	5.4	7.8	9.9	6.9	.000148"

CHART NO. 3  
 QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
 EFFECTS OF BASE METAL AND TIN-NICKEL PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
5	4.0	9.5	2.3	0.8	2.2	6.1	8.9	4.8	.000270" to .000298"
6	4.2	9.9	3.0	2.4	2.4	5.7	9.9	5.4	.000306" to .000366"
2	4.6	10.0	3.8	2.2	3.1	7.3	10.0	5.9	.000419" to .000479"
3	5.5	10.0	4.5	2.9	3.0	8.6	9.2	6.2	.000500" to .000524"
2	7.8	10.0	7.6	3.3	3.7	9.3	10.0	7.4	.000560" to .000603"
1	9.8	10.0	6.5	5.1	3.7	10.0	9.8	7.8	.000736"
Averages 6.0		9.9	4.6	2.8	3.0	7.8	9.6	6.3	.000406"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
 EFFECTS OF BASE METAL AND OROTEMP GOLD OVER NICKEL PLATING

2	2.3	10.0	10.0	10.0	4.6	10.0	10.0	8.1	Au.000034" to .000044" Ni.000036" to .000052"
2	7.6	10.0	10.0	10.0	7.2	10.0	10.0	9.3	Au.000038" to .000052" Ni.000086" to .000099"
5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000053" to .000209" Ni.000102" to .000222"
Averages 6.6		10.0	10.0	10.0	7.3	10.0	10.0	9.1	Au.000093" Ni.000127"

CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROSENE GOLD OVER NICKEL PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
3	9.7	10.0	10.0	10.0	5.4	10.0	10.0	9.3	Au.000042" to .000050" Ni.000043" to .000055"
3	8.5	10.0	10.0	9.2	7.0	10.0	10.0	9.2	Au.000049" to .000108" Ni.000085" to .000095"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000054" Ni.000209"
5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000104" to .000217" Ni.000091" to .000214"
Averages 9.6		10.0	10.0	9.8	8.1	10.0	10.0	9.6	Au.000117" Ni.000119"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX CI GOLD OVER NICKEL PLATING

2	6.3	10.0	10.0	10.0	7.4	10.0	10.0	9.1	Au.000044" to .000060" Ni.000055" to .000065"
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QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND TEMPEREX S GOLD OVER NICKEL PLATING

1	7.0	10.0	10.0	10.0	10.0	9.7	10.0	9.5	Au.000054" Ni.000054"
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CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND HARD GOLD OVER NICKEL PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
2	7.7	10.0	8.7	10.0	7.6	10.0	10.0	9.1	Au.000042" to .000044" Ni.000041" to .000043"
1	10.0	10.0	10.0	5.5	2.7	10.0	10.0	8.3	Au.000059" Ni.000089"
7	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000056" to .000190" Ni.000094" to .000203"
Averages 9.2		10.0	9.6	8.5	6.8	10.0	10.0	9.1	Au.000100" Ni.000126"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX N GOLD OVER NICKEL PLATING

3	9.9	10.0	9.9	10.0	8.9	10.0	10.0	9.8	Au.000049" to .000053" Ni.000048" to .000097"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000047" Ni.000216"
5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000098" to .000216" Ni.000090" to .000222"
Averages 9.9		10.0	9.9	10.0	9.6	10.0	10.0	9.9	Au.000101" Ni.000130"

CHART NO. 3

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC EFFECTS OF BASE METAL AND AUTRONEX C GOLD OVER NICKEL PLATING

All figures are averages of quality assurance points attained by individual plating tests:

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb ERS	Se Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
2	9.9	10.0	10.0	10.0	8.7	10.0	10.0	9.8	Au.000046" to .000055" Ni.000046" to .000064"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000088" Ni.000245"
1	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Au.000149" Ni.000244"
Averages	10.0	10.0	10.0	10.0	9.6	10.0	10.0	9.9	Au.000087" Ni.000150"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC EFFECTS OF BASE METAL AND BRIGHT GOLD OVER NICKEL PLATING

3	7.5	10.0	9.0	10.0	9.6	10.0	10.0	9.4	Au.000044" to .000046" Ni.000050" to .000067"
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QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC EFFECTS OF BASE METAL AND OROTEMP GOLD OVER RHODIUM OVER NICKEL PLATING

1	9.5	10.0	10.0	10.0	10.0	10.0	10.0	9.9	Au.000030" Rh.000050" Ni.000155"
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CHART NO. 3

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROSENE GOLD OVER SILVER PLATING

All figures are averages of quality assurance points attained by individual plating tests

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
1	1.3	10.0	1.5	7.0	5.2	5.8	9.1	5.7	Au.000052" Ag.000100"
2	2.7	7.9	2.4	3.6	3.5	3.1	10.0	4.7	Au.000055" to .000059" Ag.000172" to .000194"
2	8.3	9.8	5.3	5.6	7.8	9.3	10.0	8.0	Au.000128" to .000152" Ag.000095" to .000099"
5	8.6	10.0	8.0	5.7	8.5	9.3	10.0	8.6	Au.000153" to .000189" Ag.000171" to .000205"
Averages	5.2	9.4	4.3	5.5	6.3	6.9	9.8	6.8	Au.000133" Ag.000160"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROTEMP GOLD OVER SILVER PLATING

2	0.7	8.5	1.9	2.7	3.3	2.2	9.8	4.2	Au.000055" to .000057" Ag.000094" to .000193"
2	4.8	9.6	2.5	4.1	4.2	5.0	9.9	5.7	Au.000111" Ag.000097"
3	6.5	10.0	5.6	7.0	6.2	6.7	10.0	7.4	Au.000149" to .000163" Ag.000096" to .000181"
Averages	4.0	9.4	3.3	4.6	4.6	4.6	9.9	5.8	Au.000112" Ag.000126"

CHART NO. 3

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX N GOLD OVER SILVER PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
2	0.5	8.7	1.8	4.9	4.2	3.5		3.9	Au.000051" to .000053" Ag.000096" to .000205"
1	3.5	10.0	5.0	3.5	4.1	7.3	10.0	6.2	Au.000097" Ag.000048"
2	10.0	10.0	8.4	10.0	8.3	10.0	10.0	9.5	Au.000157" to .000201" Ag.000045"
3	9.4	10.0	7.3	6.8	6.8	8.8	10.0	8.4	Au.000138" to .000149" Ag.000098" to .000193"
Averages	5.9	9.7	5.6	6.3	5.9	7.4	10.0	7.0	Au.000124" Ag.000114"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND AUTRONEX C GOLD OVER SILVER PLATING

1	10.0	10.0	9.1	6.1	6.1	10.0	10.0	8.8	Au.000123" Ag.000218"
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CHART NO. 3  
QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND HARD GOLD OVER SILVER PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
1	0.2	6.7	0.0	2.5	2.6	2.5	10.0	3.5	Au.000050" Ag.000106"
1	1.4	7.0	2.8	2.8	4.3	2.3	10.0	4.4	Au.000055" Ag.000209"
1	4.1	10.0	3.0	3.5	4.1	7.0	10.0	6.0	Au.000096" Ag.000091"
2	4.3	9.9	3.5	3.3	5.6	5.8	9.9	6.0	Au.000118" to .000119" Ag.000089" to .000098"
2	8.1	10.0	5.4	7.5	6.5	9.3	10.0	8.1	Au.000137" to .000147" Ag.000094" to .000102"
2	9.7	10.0	5.0	8.8	6.9	8.4	10.0	8.4	Au.000148" to .000181" Ag.000097" to .000185"
Averages	4.6	8.9	3.3	4.7	5.0	5.9	10.0	6.1	Au.000117" Ag.000116"

CHART NO. 3

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND RHODIUM PLATING

All figures are averages of quality assurance points attained by individual plating tests.

No. of Tests Avg.	Average of Tests								Plating Thickness
	Pb BRS	Be Cu	Cr Cu	Pb Cu	Te Cu	P BRZ	Ni Ag	Averages	
3	0.5	6.1	0.0	0.0	0.9	1.7	6.6	2.3	.000029" to .000036"
2	0.3	6.0	0.0	0.0	2.3	3.4	7.2	2.7	.000045" to .000047"
Averages	0.4	6.1	0.0	0.0	1.6	2.6	6.9	2.5	.000037"

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND RHODIUM OVER SILVER PLATING

2	4.7	8.3	1.8	2.5	3.9	4.0	7.3	4.6	Rh.000049" Ag.000138" to .000195"
---	-----	-----	-----	-----	-----	-----	-----	-----	--------------------------------------

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND RHODIUM OVER NICKEL PLATING

1	6.4	10.0	5.8		9.1	10.0	10.0	8.6	Rh.000045" Ni.000165"
---	-----	------	-----	--	-----	------	------	-----	--------------------------

QUALITY ASSURANCE EVALUATION OF PLATED LAYER BASED ON CHARACTERISTIC  
EFFECTS OF BASE METAL AND OROSENE GOLD OVER RHODIUM PLATING

1	4.7	10.0	10.0	10.0	10.0	10.0	10.0	9.2	Au.000045" Rh.000056"
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#### XIV.

#### DISCUSSION OF PLATING COMBINATIONS - CHART 4

The purpose of this chart is to make comparisons between various plating combinations as a function of the plating parameters shown. This comparison can be made by referencing the quality assurance ratings shown on this chart. The following describes Chart 4, pages 155 and 156, and includes observations and conclusions made thereof:

The four major vertical columns represent different types of gold plating. These columns are subdivided into the basis metals from which this plating data was taken. Note that the tellurium copper basis metal was machined into male and female MIL-C-26636 contacts.

The three major horizontal sections denote the three plating combinations from which data was obtained. Those plating combinations include: gold over basis metal; gold over silver over basis metal; and gold over nickel over basis metal. The individual horizontal columns are I-IX and represent particular plating thicknesses for the three referenced plating combinations. For example, the row labeled "III, Gold over Silver" represents platings in which we plated from 35 to 60 millionths of an inch of gold over 75 to 125 millionths of an inch of silver. Each horizontal four block section included data from one plated lot and each of these individual blocks contains porosity, thickness, and microfinish readings for each of the basis metals and plated combinations outlined. In the vertical columns labeled "tellurium copper," note that there were no microfinish readings given. This was due to limitations caused by the part configuration.

It should be noted, relative to the porosity readings shown within this chart and throughout this report, that the rating method was not interpolated as a function of surface area. In other words, where part areas varied from one basis metal to another, no adjustments were made. This was basically due to the fact that the small variation in area seemed to have little or no affect on porosity. The surface areas are: leaded copper 0.36 in<sup>2</sup>; tellurium copper (male contact) 0.28 in<sup>2</sup>; tellurium copper (female contact) 0.31 in<sup>2</sup>, with all other piece parts at 0.25 in<sup>2</sup>.

### Observations and Conclusions

The following observations and conclusions were made relative to the data shown in Chart 4:

- A. Note the variation in porosity on male and female contacts as well as on the various plated basis metals.
- B. The data shows variation in porosity for different types of gold as well as for various plating thicknesses and plating combinations.
- C. It should be noted that a high microfinish rating is an indication of an improved microfinish due to the plating.
- D. There were no porosity tests conducted for gold over nickel plating with thicknesses greater than 50 millionths of an inch of gold over 200 millionths nickel. This was due to the fact that almost all platings of this thickness combination gave porosity ratings of 10. Thus, all gold over nickel platings of greater thicknesses were arbitrarily given a porosity rating of 10.
- E. Gold over silver does not appear to give as high a level of quality assurance as gold over nickel based on the porosity readings shown herein. In many cases, increasing the silver thickness tends to decrease the porosity rating. These decreased ratings seem to be equivalent to those obtained from an equal thickness of gold plated on basis metal. This result could conceivably be caused by the failure of the porosity test to measure strictly the accessibility of basis metal. However, it seems more likely that it does result from rapid lateral diffusion of test solutions through the silver layer after penetrating the gold layer. The test solution in contact with silver will react liberating a substantial amount of heat which in turn will speed up the reaction and diffusion rate through silver.

Although the porosity failure in the gold over silver platings may be a little more severe than what would be expected had we measured strictly "basis metal accessibility" we feel that the porosity rating given is a good measure of the quality assurance.

- F. Note that for the same approximate total thickness, ( $.60 \times 10^{-4}$  inches over  $.87 \times 10^{-4}$  inches) HG Gold over silver plating has a porosity of 3.75, and ( $.62 \times 10^{-4}$  inches over  $.75 \times 10^{-4}$  inches) HG Gold over nickel has a porosity of 10. Similar comparisons can be made for the other types of gold plating.

- G. Note the large decrease in porosity with increasing silver thickness for the same gold platings of approximately .000050 inches gold over leaded copper. Very little change in this respect is evident for the similar platings over leaded brass.

C H A R T  
P L A T I N G

		OROSENE				OROTEMP	
		Pb BRS	Pb Cu	Te Cu (Male)	Te Cu (Female)	Pb BRS	Pb Cu
I Au/B	Porosity Thickness Micro Finish	8.72 113/B 1.0	10.0 Same 1.0	8.01 Same	10.0 Same	6.34 114/B 1.0	10.0 Same 0.0
II Au/B	Porosity Thickness Micro Finish	10.0 135/B 1.0	10.0 Same 1.0	10.0 Same	10.0 Same	10.0 243/B 2.0	10.0 Same 1.0
III Au/Ag	Porosity Thickness Micro Finish	4.95 49/111 0.0	7.52 Same 1.0	7.61 Same	6.99 Same	2.28 37/78 2.0	3.72 Same 0.0
IV Au/Ag	Porosity Thickness Micro Finish	5.11 56/187 1.0	2.22 Same 1.0	5.11 Same	4.12 Same	2.28 44/139 2.0	1.73 Same 2.0
V Au/Ag	Porosity Thickness Micro Finish	10.0 148/97 1.0	10.0 Same 1.0	10.0 Same	8.19 Same	10.0 145/90 3.0	8.60 Same 1.0
VI Au/Ag	Porosity Thickness Micro Finish	9.79 140/177 1.0	5.93 Same 1.0	8.85 Same	10.0 Same	7.54 133/187 3.0	7.16 Same 1.0
VII Au/Ni	Porosity Thickness Micro Finish	10.0 84/67 3.0	10.0 Same 2.0	10.0 Same	9.12 Same	10.0 54/75 1.0	10.0 Same 1.0
VIII Au/Ni	Porosity Thickness Micro Finish	10.0 76/154 2.0	10.0 Same 3.0	10.0 Same	10.0 Same	10.0 55/151 1.0	10.0 Same 2.0
IX Au/Ni	Porosity Thickness Micro Finish	10.0 115/94 2.0	10.0 Same 1.0	10.0 Same	10.0 Same	10.0 104/74 2.0	10.0 Same 1.0

\* Thicknesses are in millionths of an inch



N O . 4

C O M B I N A T I O N S

OROTEMP		HG GOLD				AUTRONEX			
Te Cu (Male)	Te Cu (Female)	Pb BRS	Pb Cu	Te Cu (Male)	Te Cu (Female)	Pb BRS	Pb Cu	Te Cu (Male)	Te Cu (Female)
9.12 Same	10.0 Same	10.0 128/P 0.0	10.0 Same 0.0	10.0 Same	10.0 Same	9.60 68/B 0.0	10.0 Same 0.0	10.0 Same	10.0 Same
10.0 Same	10.0 Same	10.0 214/B 2.0	10.0 Same 2.0	10.0 Same	10.0 Same	10.0 212/B 1.0	10.0 Same 1.0	10.0 Same	10.0 Same
2.92 Same	5.0 Same	3.75 60/87 1.0	6.11 Same 0.0	4.61 Same	6.11 Same	3.34 38/86 2.0	4.75 Same 1.0	5.23 Same	6.11 Same
4.35 Same	3.72 Same	2.92 60/173 0.0	1.64 Same 0.0	2.10 Same	2.76 Same	2.88 43/180 0.0	3.28 Same 2.0	3.61 Same	4.43 Same
8.72 Same	9.12 Same	10.0 159/57 0.0	7.92 Same 0.0	9.60 Same	7.84 Same	10.0 100/99 0.0	8.39 Same 2.0	10.0 Same	10.0 Same
6.77 Same	7.61 Same	9.27 156/187 0.0	8.39 Same 0.0	8.72 Same	8.49 Same	9.61 99/174 1.0	8.19 Same 1.0	10.0 Same	10.0 Same
10.0 Same	10.0 Same	10.0 62/76 0.0	10.0 Same 1.0	10.0 Same	10.0 Same	10.0 40/101 1.0	10.0 Same 3.0	10.0 Same	10.0 Same
10.0 Same	10.0 Same	10.0 69/150 2.0	10.0 Same 3.0	10.0 Same	10.0 Same	10.0 30/129 1.0	10.0 Same 1.0	10.0 Same	10.0 Same
10.0 Same	10.0 Same	10.0 103/86 1.0	10.0 Same 3.0	10.0 Same	10.0 Same	10.0 66/79 1.0	10.0 Same 3.0	10.0 Same	10.0 Same

XV.

### POROSITY TEST METHOD

#### A. Purpose

1. The principal purpose of an electrodeposited plating on a connector contact is to prevent corrosion. The electrodeposited metal prevents corrosion by shielding the basis metal from exposure to environmental conditions.
2. Plating porosity varies, depending on the plating process as well as the metal deposited. Consequently, utilization of a suitable porosity test is essential for quality assurance evaluations of plating processes as applied to connector contacts.

#### B. Methods Considered

1. Several methods of measuring porosity of platings are available. Each of the methods reported here rely on a technique of measuring the ability of a chemical or electrolyte passing through the plated layer by way of the pores and registering a porosity test.

#### C. Porosity Tests

1. Gas Flow: This method is essentially a measurement of the rate of flow of gas through a plated layer removed from the basis metal. This method is quantitative but requires costly equipment and separate specimens. It is considered impractical for our purposes.
2. Salt Spray: This method consists of exposing the plating to an atomized atmosphere of a salt solution and visually estimating the degree of corrosion. This method is not quantitative and requires a long exposure time. It is considered impractical for our purposes.
3. Electrographic: This method consists of electrolytically oxidizing the surface into an adjacent paper soaked with an electrolyte. The oxidized products in the paper will include oxidized components of the basis metal if the plating is porous. The porosity of the plating is determined by colored spots on the paper caused by the presence of some basis metal components.

4. Soak: This is a colorimetric technique of measuring the amount of basis metal dissolved in a test solution. The test solution is designed to only chemically attack the basis metal and change color as a function of the metal available. This method is quantitative but requires a lengthy soak period for platings such as gold. We have applied this porosity test method to silver platings of this contract. Silver platings were found to be much more porous than gold.
5. Ultrasonic Soak: This method consists of a soak method to which ultrasonic agitation is introduced. This is the method we have chosen for work conducted herein on gold, nickel, rhodium and tin-nickel platings because it combines the advantages of a quantitative measurement with the speed provided by ultrasonic agitation.

D. Ultrasonic Test Method (Ultrasonic Soak)

This method, excluding ultrasonic agitation, is similar to that described by Martin S. Frant<sup>8</sup>.

Figure 6, page 162, is a sketch of the test apparatus. The test specimen is suspended into a test tube containing a solution of ammonium persulphate and ammonium hydroxide. After a timed period with ultrasonic agitation, the test solution is compared to standard color solutions in order to estimate the quantity of copper extracted.

The ultrasonic porosity test developed and employed for the evaluation of contract platings follows:

Equipment

1. Narda Model G601 Ultrasonic Generator (40 KC)\*, or equivalent.
2. Narda Model NT603 Ultrasonic Tank, or equivalent.

\*Narda Ultrasonics, Inc.; Mineola, New York

<sup>8</sup>Frant, Martin S., "Porosity Measurements on Gold Plated Copper", Journal of the Electrochemical Society, Vol. 108, No.8, Aug.1961

3. A special circular test tube rack was designed to rotate twelve test tubes in an ultrasonic bath as part of our porosity test method. This rack rotates at the rate of 10 revolutions per minute. The diameter of this rack was 5 inches with the diameter of the test tubes at 3-7/8 inches on center. 20 x 150 mm test tubes were used which extended 1.5 inches into the ultrasonic bath solution.

#### Standard Solutions

The concentration of copper used in the standard solutions were from 10 to 50 parts per million at 5 parts per million increments, from 50 to 100 parts per million in 10 parts per million increments and from 100 to 500 parts per million in 50 parts per million increments. The solutions consisted essentially of equal parts by volume of 1 molar  $(\text{NH}_4)_2 \text{SO}_4$  and concentrated ammonia. The level of each solution was maintained by the addition of concentrated ammonia. The same standard solutions were used for all the tests.

#### Test Solution

The test solution consists of 50% by volume of concentrated  $\text{NH}_4\text{OH}$  and 50% by volume of 1M  $(\text{NH}_4)_2 \text{S}_2\text{O}_8$ .

#### Test Procedure

The ultrasonic tank was filled with water to a mark placed 3.5 inches from the top of the tank. The water was previously adjusted to a temperature of  $30^\circ\text{C} \pm 3^\circ\text{C}$  and five (5) grams of sodium lauryl sulfate was added to the bath. The unit was turned on and allowed to run for a minimum of three minutes before the first test. (This prevents any transient effect resulting from warm-up).

The appropriate test tubes were suspended in the ultrasonic tank by means of the rotating rack and were filled to a mark designating (10 ml) of test solution. All twelve test tubes were in place and filled to the proper level for each test run. The ultrasonic plate current was then adjusted to a reading of about 50, and the parts were inserted into the test tubes at the end of a fixture which securely held the parts throughout the test run. At the same instant, a timer was started and the plate current adjusted to 50 as read on the generator dial. (The plate current was maintained at 50 throughout the entire test procedure). Rotation of the rack was then begun and allowed to run for the period allotted that test.

At the termination of this test, the parts were removed, rinsed, and stored in individual lot containers. The amount of copper extracted was then determined by the degree of color of the test solution as compared to the set of standard solutions.

The rating assigned to each part was calculated from the formula:  $RATING = 15 - 5 \times \log(PPM)$  where (PPM) is parts per million of copper extracted into the 10 ml test solution during the test procedure. If more than one part of the same kind were tested, the average (PPM) was substituted into the formula to obtain the average rating for that group. When concentrations were less than 10 PPM, parts were rated as having a porosity of 10. The formula  $R = 15 - 5 (\log \text{ of PPM})$  is graphed on page 163.

<u>Applications</u>	<u>Test Time</u>
Gold Only	4 Min.
Gold/Silver	4 Min.
Rhodium Only	2 Min.
Rhodium/Gold	2 Min.
Nickel Only	6 Min.
Gold/Nickel	6 Min.
Tin-Nickel Alloy	5 Min.

#### Soak Method Employed for Silver Platings

This method of porosity testing was applied only to silver platings. No ultrasonic agitation was employed in this method. The solution consists of 50% by volume of concentrated ammonia and 50% by volume of 0.2 molar ammonium persulfate  $(NH_4)_2 S_2O_8$ . The parts were submerged in this solution for a period of five minutes. 10 ml of test solution per part was used. The same method of rating as that employed in the ultrasonic tests was used here.

#### Discussion of the Ultrasonic Method

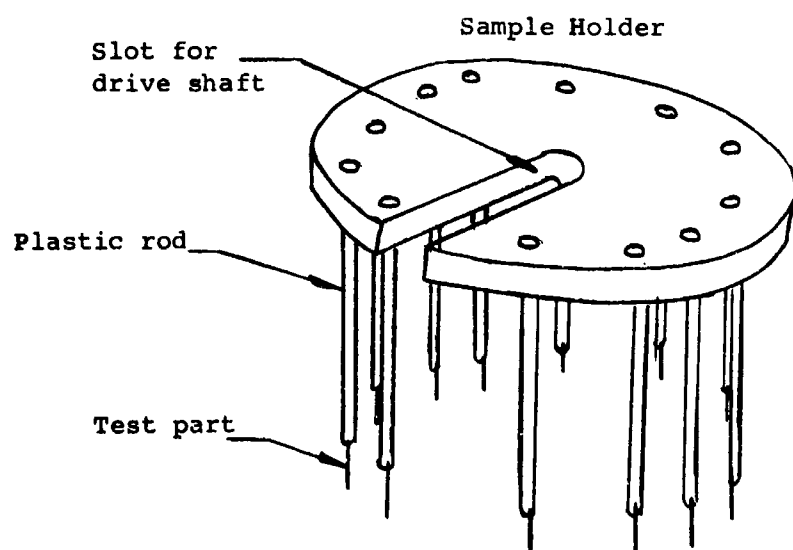
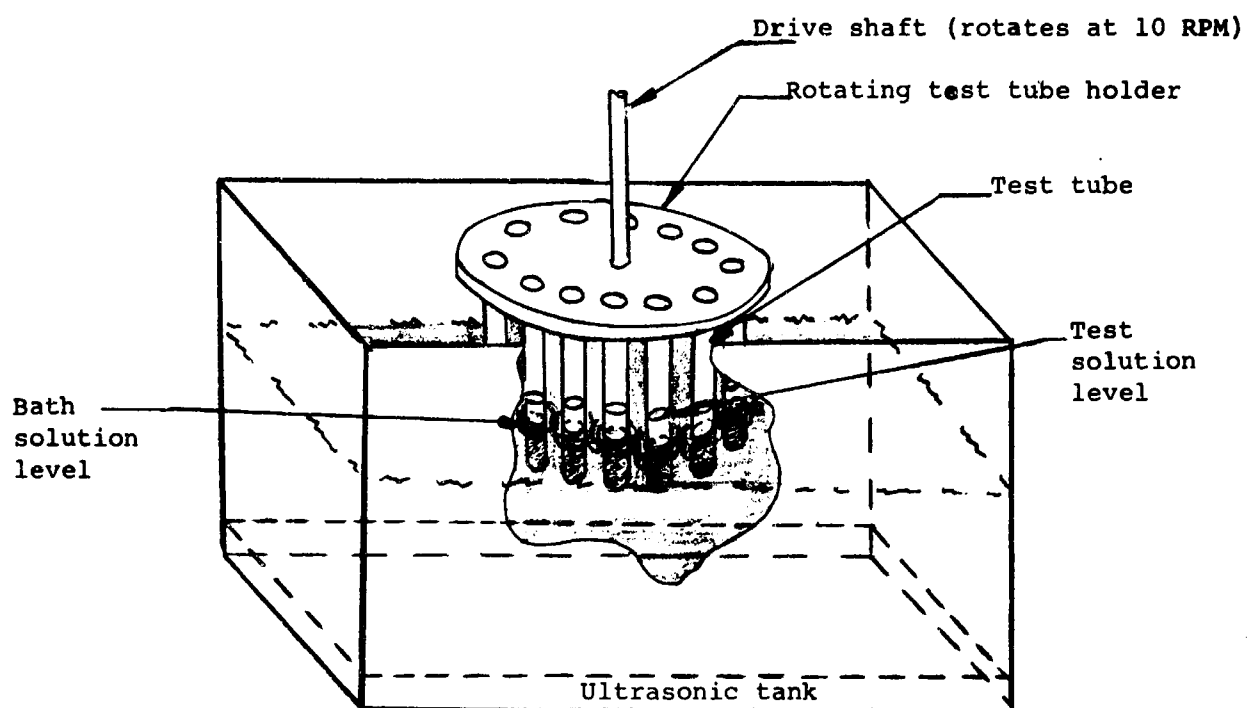
The test tubes were rotated in a circular path within the ultrasonic tank in order to equalize the agitation history of the test solutions. There appeared to be evidence that agitation varies with position within the tank.

Ultrasonic agitation greatly accelerates the rate of removal of basis metal through platings. In some cases, it has been observed that the quantity of copper removed by a four-minute ultrasonic test required two days exposure to the test solution when no ultrasonic agitation was applied. Also, it was observed that the rate of dissolution of unplated leaded brass is five times greater with ultrasonic agitation than without. What explanation is there for these observations? The key to this question lies on the rate of solution replenishment at the site of dissolution and the ability of the solution to migrate through plating pores usually blocked as a result of surface tension. The powerful but minute implosions characteristic of ultrasonic agitation greatly enhances such solution replenishment especially in pores. These implosions overpower surface tension and allow the solution to migrate rapidly through the pores of the plating.

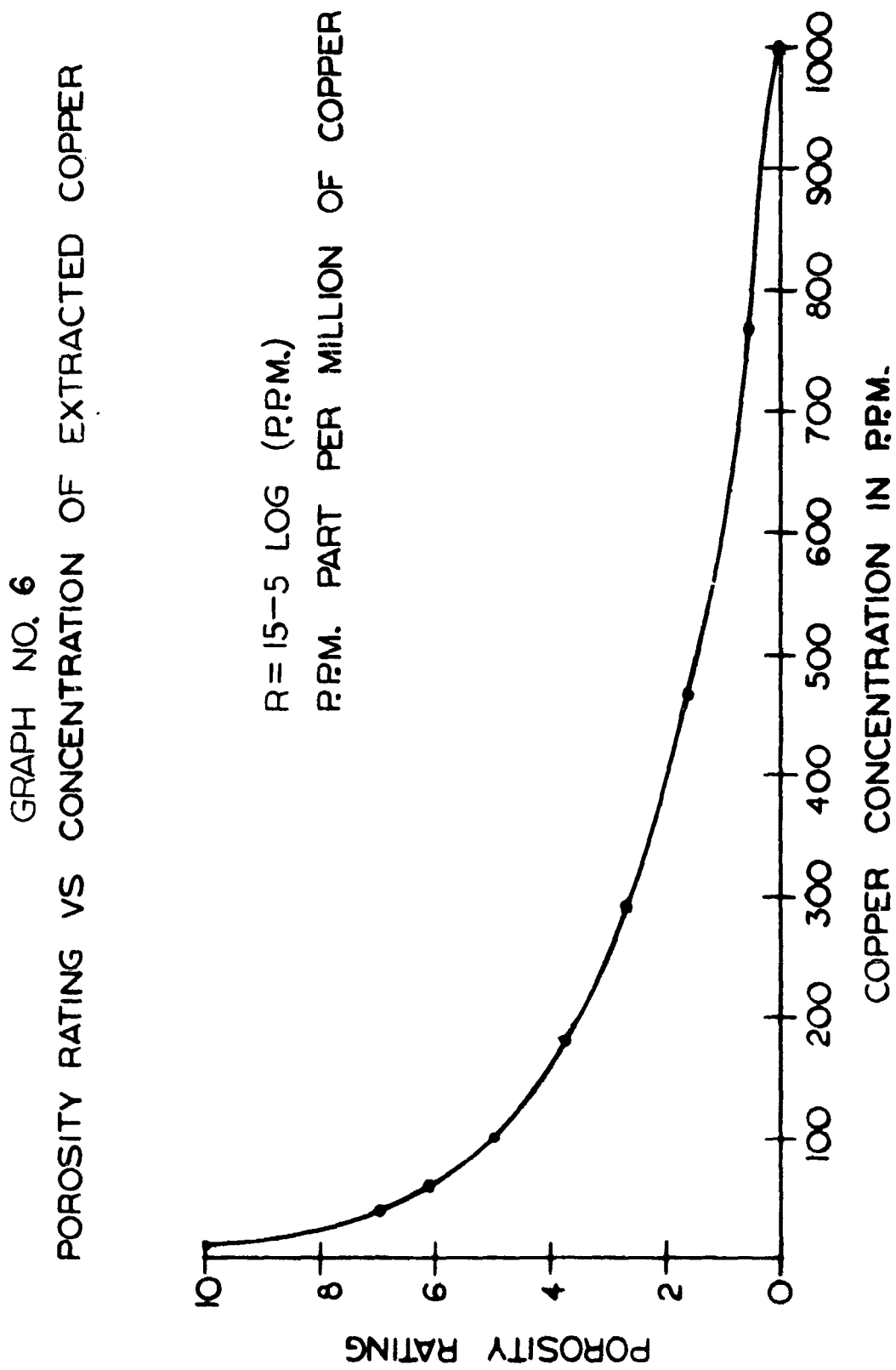
The major portion of the basis metal extracted appears to be from pits which expose the basis metal. These pits vary in size. They are formed after some undermining of the plated layer and result from eruptions promoted by ultrasonic agitation. The basis metal is much more rapidly dissolved after these pits have formed. To a large degree, the porosity test measures the ease with which such pits are formed. Nevertheless, this is primarily dependent on the porosity of the plating.

An added bonus provided by the ultrasonic test is that the porosity results are strongly affected by basis metal defects such as scratches, nicks, and poor adhesion. The porosity test usually gives a poorer rating when such defects are present. This feature makes the ultrasonic porosity test very valuable in assessing a plating's over-all quality.

The correlations of the results of the porosity tests with factors such as thickness and plating types which were obtained are evidence that this porosity test is reliable and useful. We feel that there is no reason some innovation of the present method could not become widely accepted as a required quality assurance test.



Porosity Test Apparatus  
Figure 6





XVI.

THICKNESS VARIATION WITHIN A GIVEN LOT (Graphs 7 through 14)

The purpose of this chart was to show what type of thickness variation existed in individual tumbler loads. It was also our purpose herein to determine whether or not the eight gallon baths being used were affecting the characteristics of the plated lots due to the limited access within the bath. In particular, this included comparatively close anodizing, high agitation, and bath concentration.

Each of the plated lots shown on these graphs was of leaded brass basis material, and was plated with all parameters at the standard level. The thickness of plate was determined by taking thickness readings on the microsectioned part in two places. The readings were made in the same two areas of each part and were averaged to arrive at the thickness value plotted.

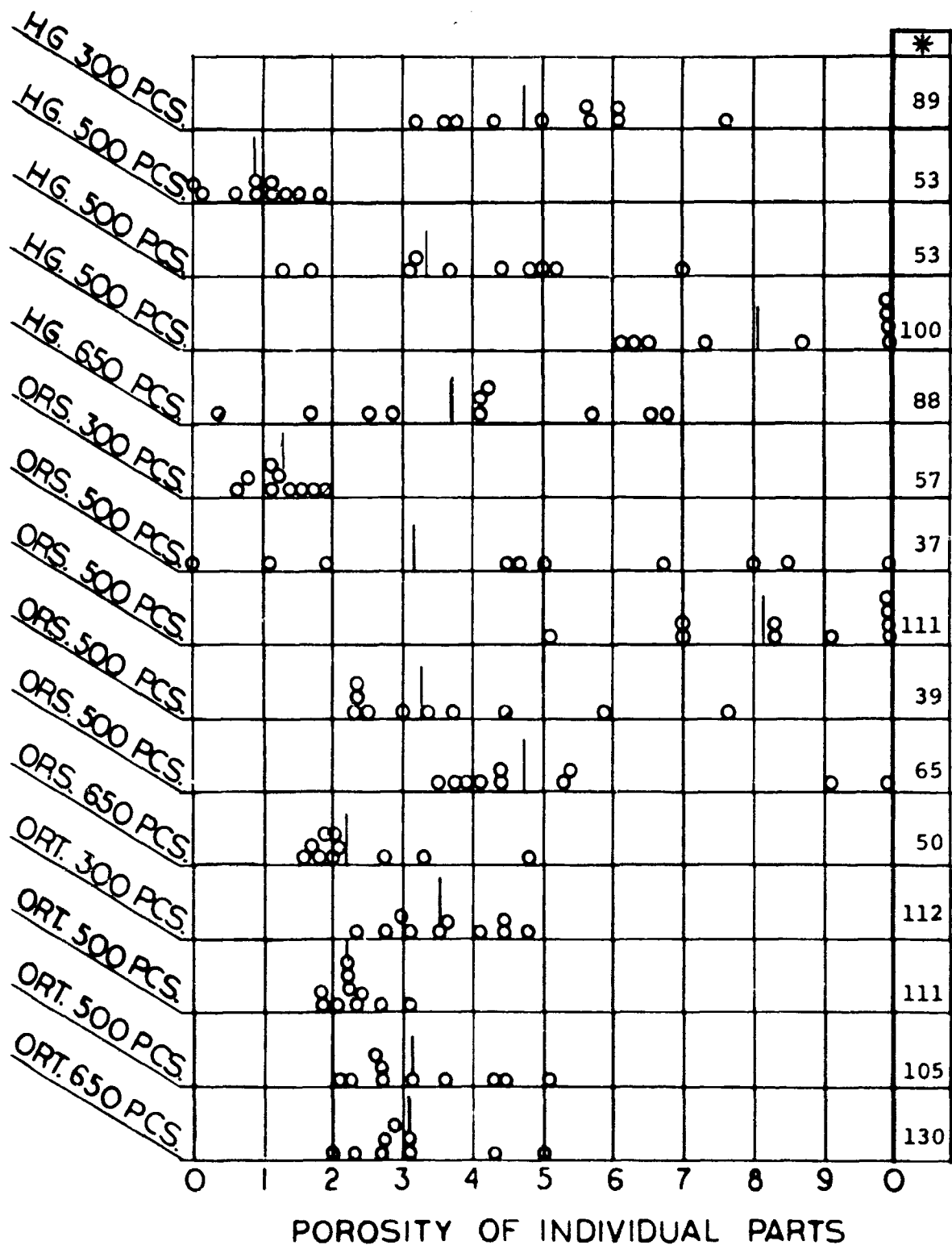
The tumblers used in these tests and through the first three-fourths of this program were standard 2" x 4" tumblers similar to those manufactured by most suppliers. In the final stages of this contract similar tumblers of the 5" x 9" size were used.

The purpose here was to use two tumbler sizes of which most of the thickness variation tests were done using the 2" x 4". The tumbler was loaded to what was considered an optimum load and then over loaded and under loaded for various tests. The primary test being to evaluate thickness distribution of plating from part to part in a load and thickness distribution over a given part as a function on any load. Although the results were not clear and defining as hoped for, they are listed below and shown on the following graphs. Note that porosity tests were done on these parts and in some cases the bath size was changed to check its effect on the porosity and thickness distribution of the plating.

The following observations were made relative to these charts:

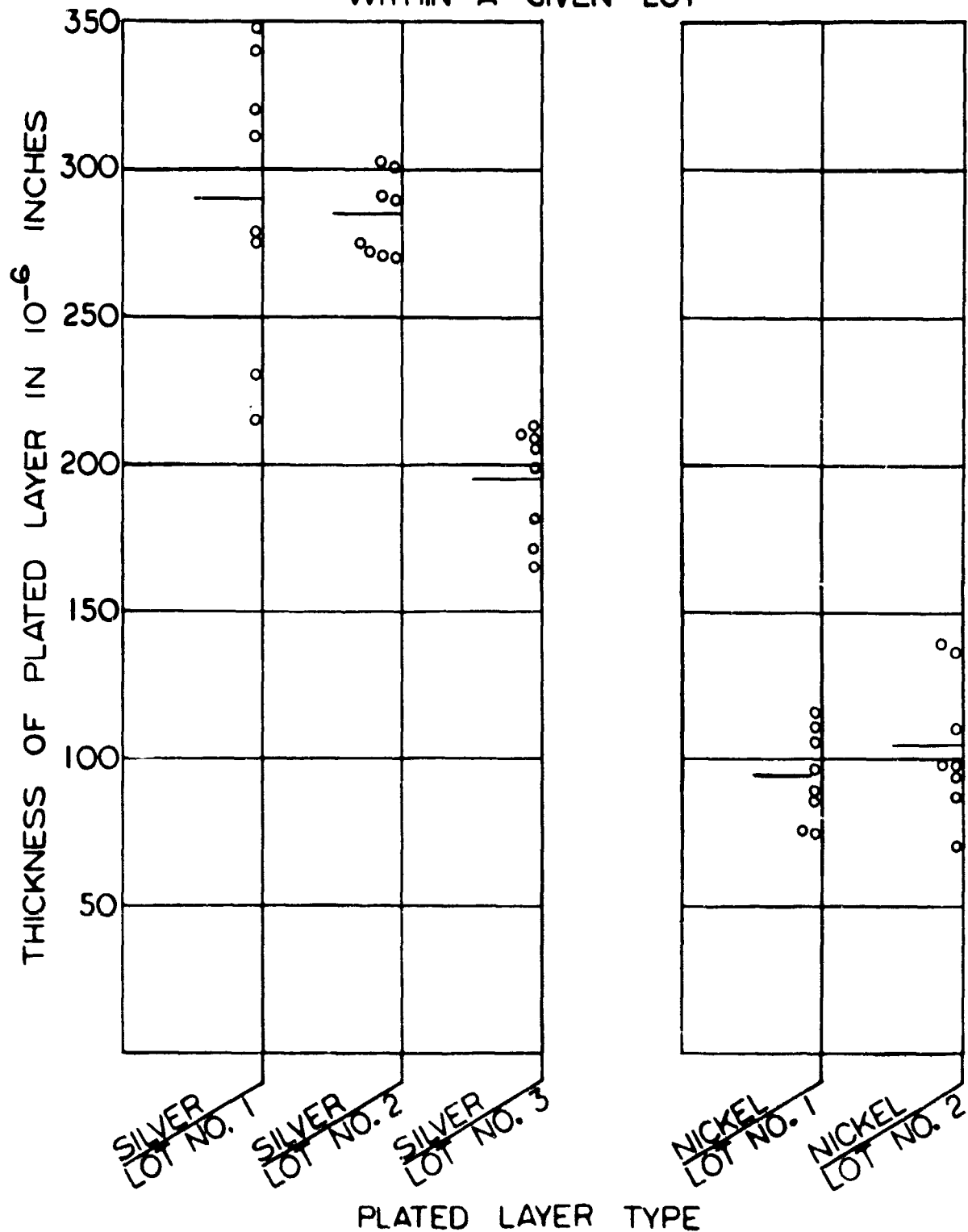
- . It is apparent that the distribution of thickness which can be expected from a given tumbler load of plated parts cannot be predicted with any high degree of accuracy.
- . There appears to be no correlation of thickness spread with the type of gold plated.
- . The ratio of thickness spread to actual thickness appears to be about the same for each of the platings tested.

GRAPH NO. 7  
POROSITY VARIATION WITHIN A GIVEN LOT



\* Average Thickness in 10<sup>-6</sup> Inches.

GRAPH NO. 8  
THICKNESS VARIATION  
WITHIN A GIVEN LOT

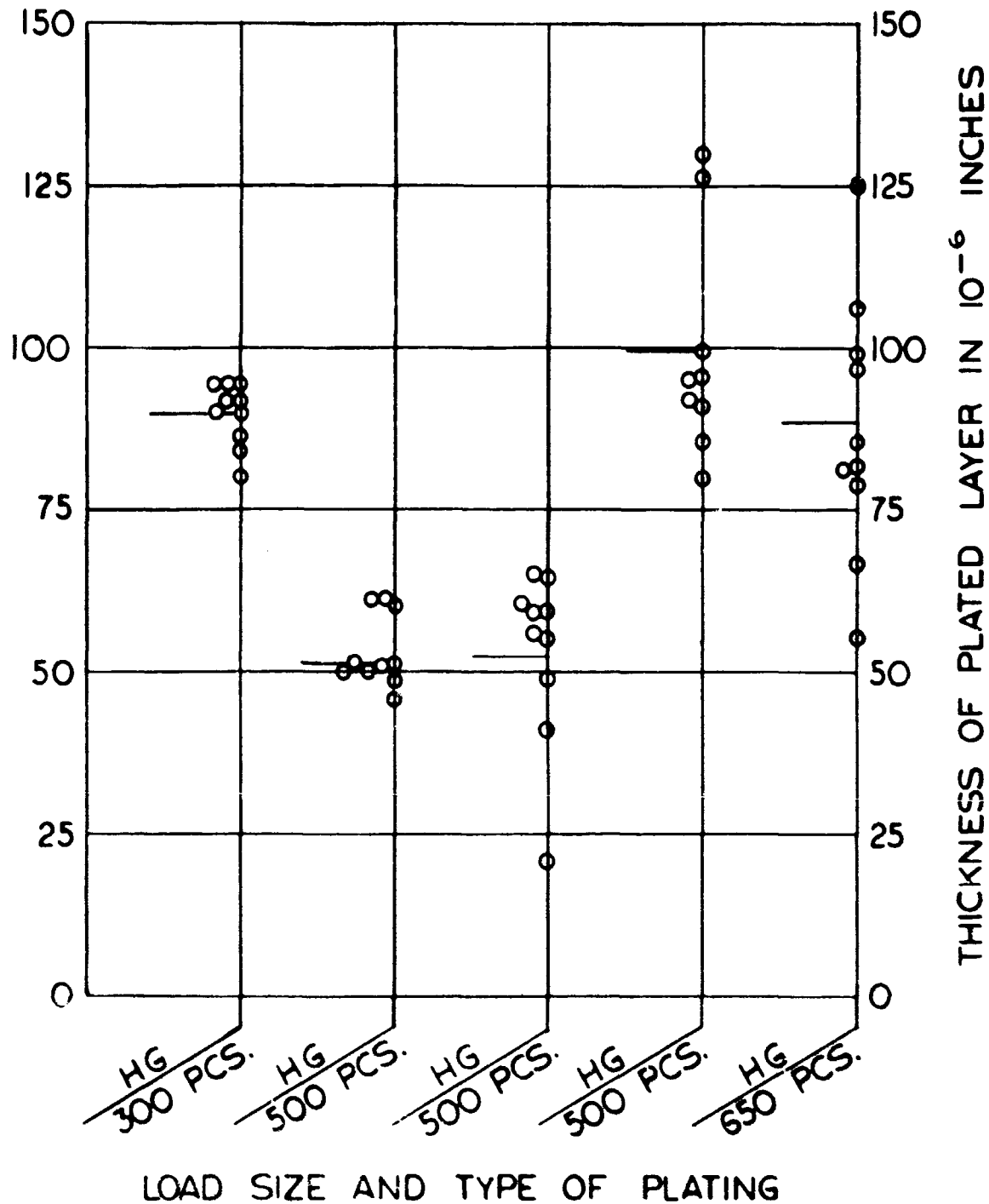


NOTE: All measurements were made on leaded brass parts taken from 500 part tumbler loads which were plated in 8 gallon baths.

# GRAPH NO. 9

THICKNESS VARIATION WITHIN A GIVEN LOT

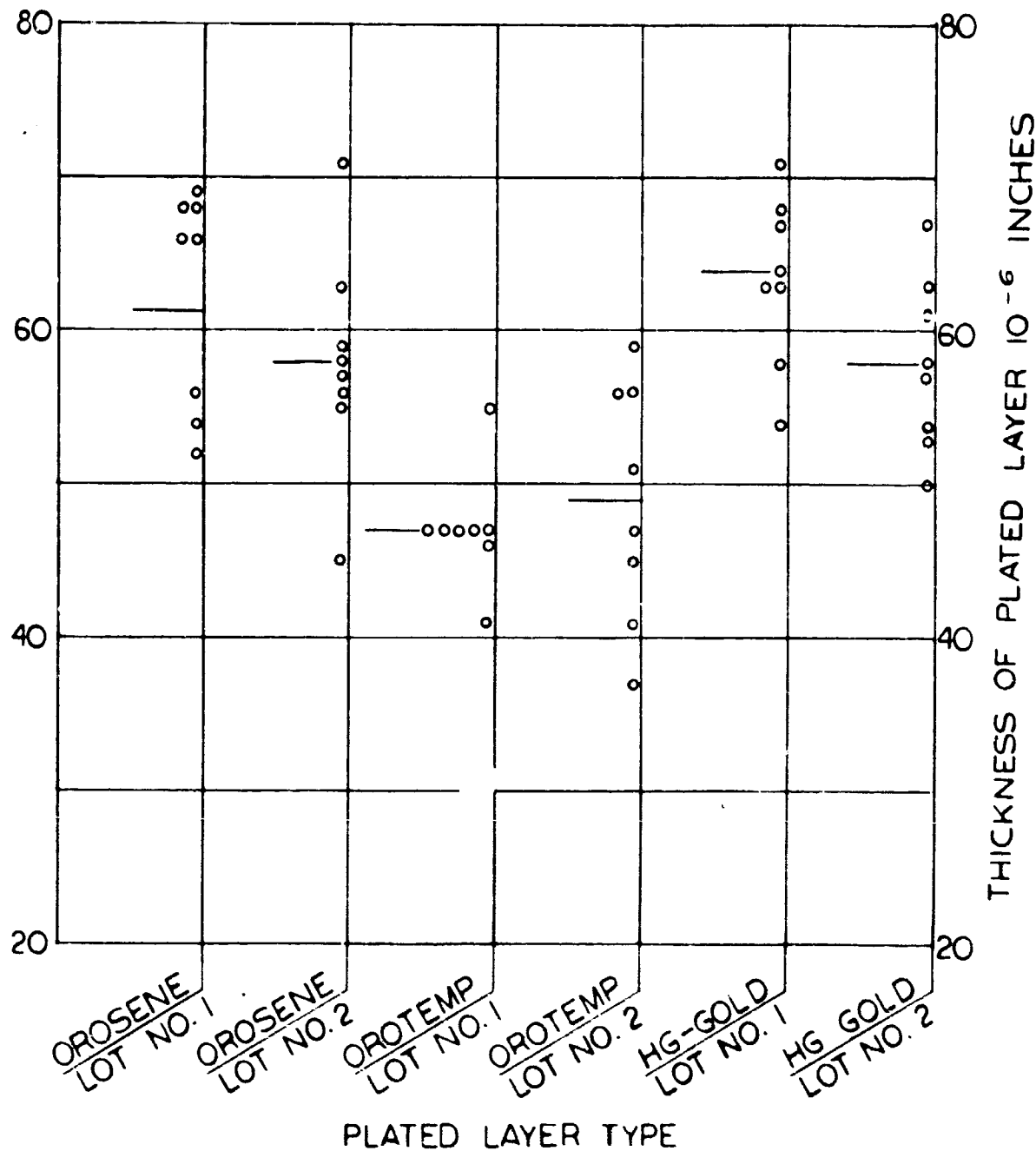
[HARD GOLD — 66 GALLON BATH]



NOTE: All measurements were made on round leaded brass parts.

GRAPH NO. 10

THICKNESS VARIATION WITHIN A GIVEN LOT

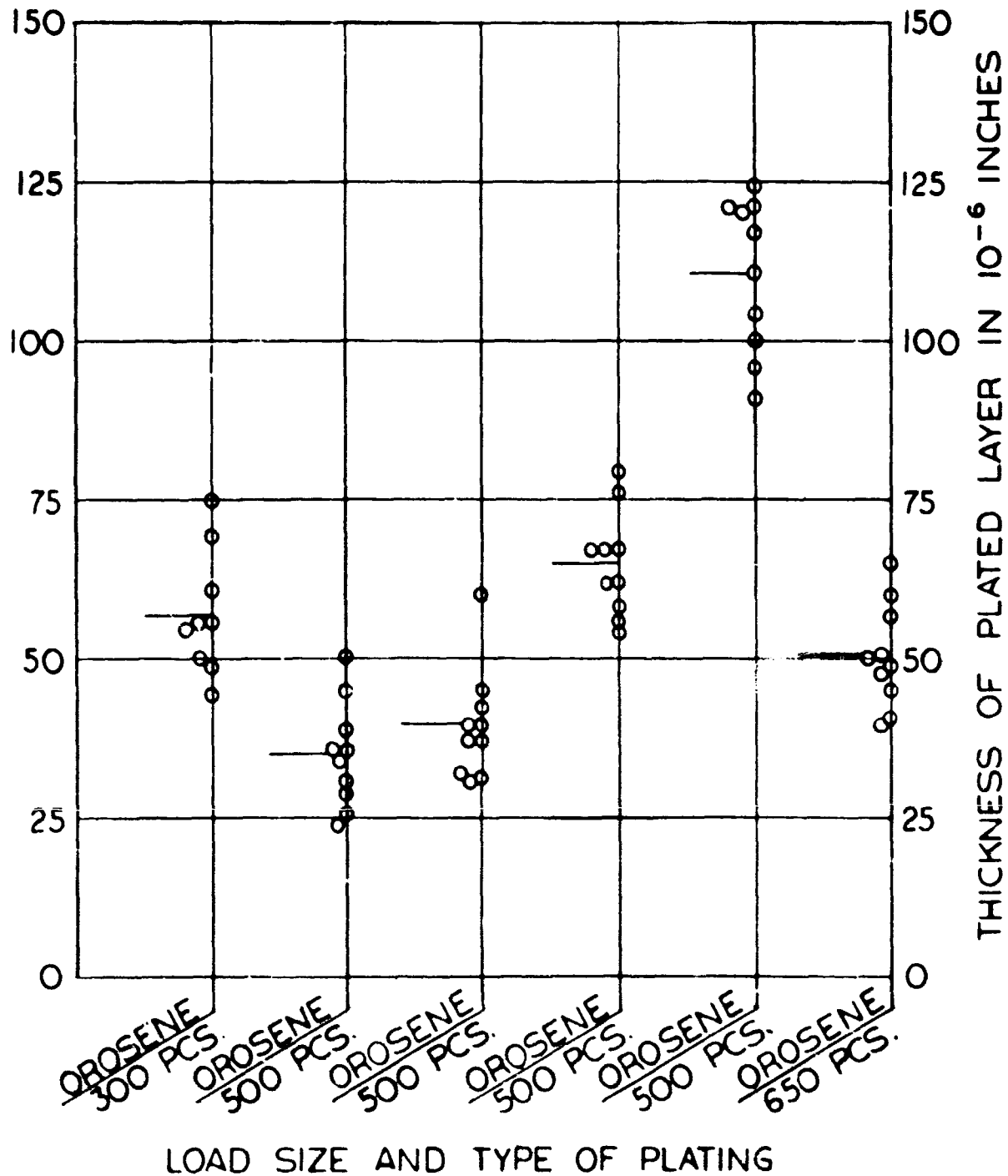


NOTE: All measurements were made on loaded brass parts taken from 500 part tumbler loads which were plated in 8 gallon baths.

# GRAPH NO. 11

THICKNESS VARIATION WITHIN A GIVEN LOT

[OROSENE GOLD - 66 GALLON BATH]

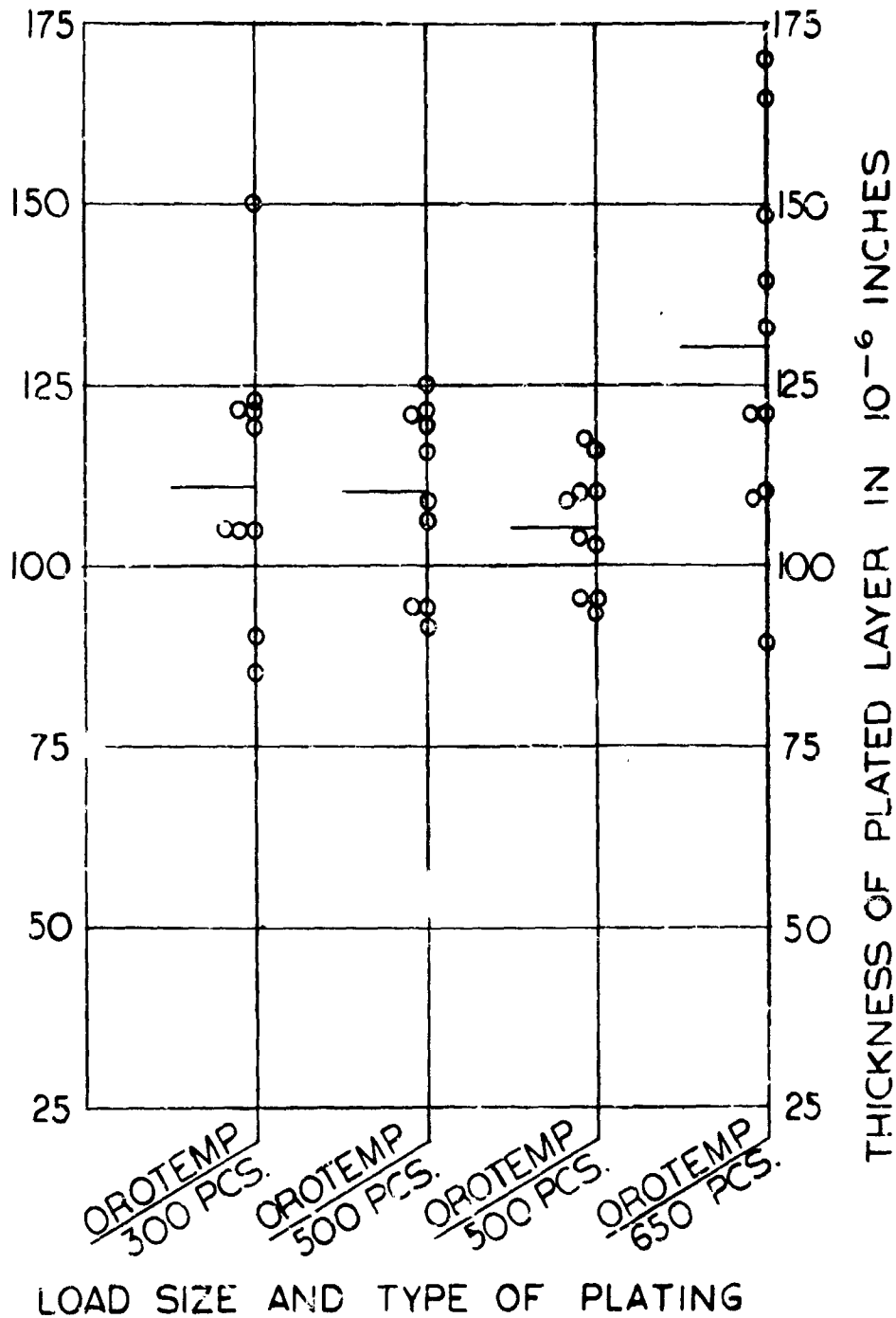


NOTE: All measurements were made on round leaded brass parts.

# GRAPH NO. 12

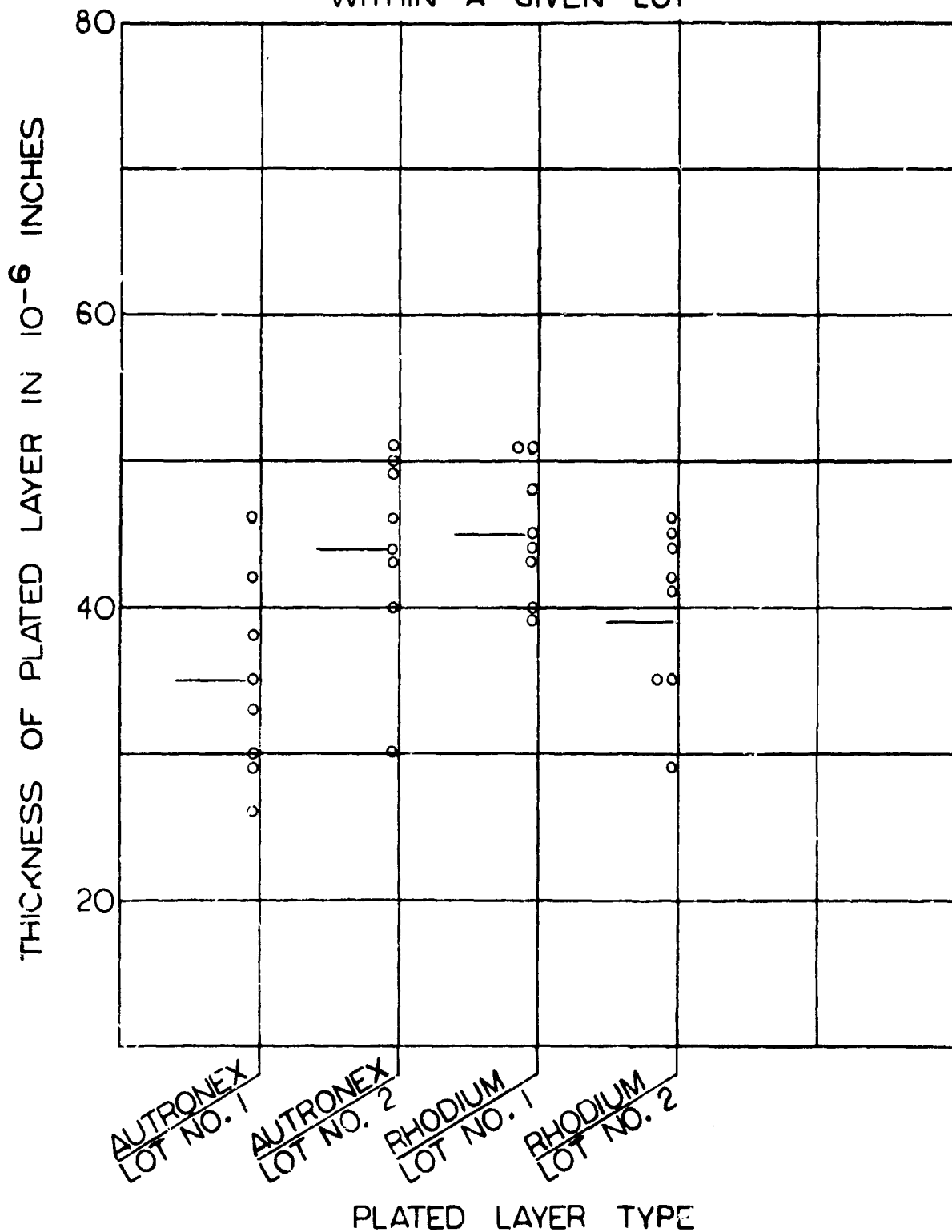
THICKNESS VARIATION WITHIN A GIVEN LOT

[OROTEMP GOLD-12 GAL. BATH]



NOTE: All measurements were made on round leaded brass parts.

GRAPH NO. 13  
THICKNESS VARIATION  
WITHIN A GIVEN LOT



NOTE: All measurements were made on leaded brass parts taken from 500 part tumbler loads which were plated in 8 gallon baths.





XVII.

MICROFINISH

Throughout this contract work microfinish tests have been made on all test lots before and after plating. This was to assure us that we were below the 10 microfinish maximum range allowed by the contract before plating and that we could follow and compare the resulting microfinish of various plated layers.

Results that have been obtained from this investigation include the fact that microfinish of the basis metal does directly effect the porosity of the plated layer. The higher or worse the microfinish the greater is the porosity of the plated layer.

It was also observed that various types of plating will result in a plated layer with a better microfinish than the basis metal had initially. In most cases, however, the microfinish was the same after plating as it was before plating. In part, this is due to the thin or less thick plating we were doing. Microfinish as well as visual inspection were both used as tests for rating the quality assurance factor of any plating completed herein.

XVIII.

WEARABILITY STUDY OF CONTACT PLATING

The wearability tests discussed herein were conducted on plated MIL-C-26636 tellurium copper contacts. These contacts were plated with 54 different plating combinations of which three male and three female contacts from each plated lot were inserted and withdrawn 500 times. The rate of the insertion and withdrawal was 420 per hour. During each cycle, each contact was continually inspected for wear. A counter was employed during this cycle from which whenever galling or intermediate wear was found, its readings were recorded on the data sheets.

The machine used to insert and withdraw these contacts was a simple mechanism with a motor, cam shaft, and a movable fixture for the mounting of the contacts. These contacts (male and female) were mounted and labeled A, B, and C. Each contact was examined throughout the wearability cycle and the data recorded relative to each contact and its position during this test.

In reviewing the data, it shows a high rate of wear relative to the number of tests that did not withstand this test. This was possibly due to slight misalignment of pins; however, this fact did not concern us because if we had had a high rate of reliability in this test, it would have been difficult to distinguish the actual wearability between plated layers without exceeding 500 insertions and withdrawals called for in the MIL-C-26500 Specification. The data obtained was reproducible and conclusive, therefore, we felt this present setup was adequate.

The contacts used in these tests were of the pencil clip design manufactured by Pyle-National Company. The pencil clip is of stainless steel and the contact of tellurium copper.

The plating combinations shown in the chart in this section consist of silver only at three thicknesses; gold only at two thicknesses; gold over silver at four thickness combinations; gold over nickel at six thickness combinations; rhodium over silver; rhodium over nickel; and gold over rhodium over nickel at one thickness combination.

All contacts were periodically examined under a 20X Microscope for wear. When a contact wore through a plated layer, the number of insertions and withdrawals was recorded. However, when the

contact showed wear through to the basis metal, the number of insertions and withdrawals were recorded and the part removed from the fixture. Any part with exposed basis metal was rated a failure. Parts that showed wear through the outer most plated layer but not through the barrier plated layer was rated poor, and all contacts not showing wear through the surface plated layer were rated good.

Chart 5, pages 176 through 186, of this report section summarizes the wearability tests conducted throughout this contract. There is a summary of Chart 3 in Report Section XVIII.

It was noted that from these wearability tests hard gold over nickel gave some of our best wear characteristics. Soft gold did not wear as well as hard golds, and gold over silver did wear better than did golds over basis metal.

In referencing Chart 5, the last column to the right entitled "Average Rating Per Lot" related to points assigned wearability tests to rate or evaluate the results. These points are obtained from three pairs of contacts being mated and unmated, and the total points from this test are averaged with points from other similar tests to arrive at the value shown here. Individually, each mated pair of contacts can attain a total of three points, thus, for any given test, a total of nine points can be totalled. The following is a breakdown of this system:

500 Insertions, No Significant Signs of Wear	= 3 Points
325 Insertions, with Barrier Layer Exposed	= 2 Points
325 Insertions, with Galling	- 2 Points
325 Insertions, any Barrier Layer Exposed before 325 Insertions	= 1 Point
325 Insertions, any Galling before 325 Insertions	= 1 Point
1 to 500 Insertions, Basis Metal Exposed	= 0 Points

Note: Only male contacts were examined for wear.

The following wearability charts include data that is an average of all plating thicknesses, number of matings and rating points assigned each wearability test. In reviewing these charts consideration should be taken to the thickness of plating from one plating combination to another. If this is done, a relative evaluation of wearability can be made. Consideration should also be made of the number of tests conducted in each case.

# CHART 5

## WEARABILITY DATA ON HARD GOLD PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
6	0.000052"	142	0.0 Pts.
3	0.000068"	208	1.0 Pts.
5	0.000098"	177	1.2 Pts.
6	0.000117"	275	1.2 Pts.
2	0.000147"	354	3.0 Pts.
3	0.000195"	364	5.0 Pts.
1	0.000237"	267	3.0 Pts.
Summary 26	Average 0.000109"	Average 230	Average 1.5 Pts.

## WEARABILITY DATA ON BRIGHT GOLD PLATING OVER BASIS METAL

8	0.000047"	150	0.0 Pts.
2	0.000060"	150	0.0 Pts.
16	0.000098"	208	0.0 Pts.
2	0.000145"	296	3.0 Pts.
Summary 28	Average 0.000084"	Average 193	Average 0.2 Pts.

CHART 5

WEARABILITY DATA ON AUTRONEX C GOLD PLATING  
OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
6	0.000050"	228	0.0 Pts.
14	0.000097"	345	2.8 Pts.
1	0.000113"	441	6.0 Pts.
2	0.000156"	413	4.5 Pts.
1	0.000204"	500	9.0 Pts.
Summary 24	Average 0.000096"	Average 332	Average 2.8 Pts.

WEARABILITY DATA ON OROSENE GOLD PLATING OVER BASIS METAL

7	0.000051"	225	0.9 Pts.
2	0.000072"	209	0.0 Pts.
7	0.000104"	343	3.4 Pts.
3	0.000157"	481	6.0 Pts.
1	0.000172"	500	9.0 Pts.
3	0.000203"	442	7.0 Pts.
Summary 23	Average 0.000108"	Average 332	Average 3.4 Pts.

CHART 5

WEARABILITY DATA ON AUTRONEX N GOLD PLATING  
OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
9	0.000050"	196	1.0 Pts.
5	0.000058"	176	0.0 Pts.
6	0.000099"	267	1.5 Pts.
3	0.000166"	442	6.0 Pts.
Summary 23	Average 0.000080"	Average 242	Average 1.6 Pts.

WEARABILITY DATA ON AUTRONEX CI GOLD PLATING  
OVER BASIS METAL

6	0.000048"	150	0.0 Pts.
1	0.000067"	150	0.0 Pts.
14	0.000099"	349	3.0 Pts.
1	0.000120"	325	3.0 Pts.
3	0.000156"	345	4.0 Pts.
Summary 25	Average 0.000094"	Average 202	Average 2.3 Pts.

# CHART 5

## WEARABILITY DATA ON OROTEMP GOLD PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
4	0.000046"	172	1.5 Pts.
3	0.000104"	228	1.0 Pts.
1	0.000166"	325	3.0 Pts.
1	0.000205"	150	0.0 Pts.
1	0.000285"	18	0.0 Pts.
Summary 10	Average 0.000116"	Average 190	Average 1.0 Pts.

## WEARABILITY DATA ON TEMPEREX S GOLD PLATING OVER BASIS METAL

6	0.000050"	150	0.0 Pts.
1	0.000061"	150	0.0 Pts.
16	0.000096"	198	0.2 Pts.
2	0.000152"	150	0.0 Pts.
Summary 25	Average 0.000089"	Average 180	Average 0.1 Pts.



# CHART 5

## WEARABILITY DATA ON HARD GOLD OVER NICKEL PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
2	Au 0.000043" Ni 0.000042"	500	7.0 Pts.
1	Au 0.000059" Ni 0.000089"	500	9.0 Pts.
5	Au 0.000087" Ni 0.000173"	500	8.0 Pts.
2	Au 0.000187" Ni 0.000148"	500	5.0 Pts.
Summary 10	Average Au 0.000100" Ni 0.000126"	Average 500	Average 7.2 Pts.

## WEARABILITY DATA ON BRIGHT GOLD OVER NICKEL PLATING OVER BASIS METAL

3	Au 0.000045" Ni 0.000057"	500	9.0 Pts.
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## WEARABILITY DATA ON AUTRONEX C GOLD OVER NICKEL PLATING OVER BASIS METAL

2	Au 0.000050" Ni 0.000055"	500	9.0 Pts.
1	Au 0.000088" Ni 0.000245"	500	9.0 Pts.
1	Au 0.000149" Ni 0.000244"	500	9.0 Pts.
Summary 4	Average Au 0.000084" Ni 0.000150"	Average 500	Average 9.0 Pts.

# CHART 5

## WEARABILITY DATA ON OROSENE GOLD OVER NICKEL PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
3	Au 0.000047" Ni 0.000050"	442	6.7 Pts.
3	Au 0.000087" Ni 0.000090"	500	9.0 Pts.
1	Au 0.000054" Ni 0.000209"	500	9.0 Pts.
5	Au 0.000189" Ni 0.000158"	500	8.8 Pts.
Summary 12	Average Au 0.000117" Ni 0.000119"	Average 485	Average 8.3 Pts.

## WEARABILITY DATA ON AUTRONEX N GOLD OVER NICKEL PLATING OVER BASIS METAL

3	Au 0.000050" Ni 0.000069"	500	9.0 Pts.
1	Au 0.000047" Ni 0.000216"	500	9.0 Pts.
4	Au 0.000152" Ni 0.000154"	500	9.0 Pts.
Summary 8	Average Au 0.000101" Ni 0.000130"	Average 500	Average 9.0 Pts.

## WEARABILITY DATA ON AUTRONEX CI GOLD OVER NICKEL PLATING OVER BASIS METAL

2	Au 0.000055" Ni 0.000060"	500	9.0 Pts.
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CHART 5

WEARABILITY DATA ON TEMPEREX S GOLD OVER NICKEL PLATING  
OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
1	Au 0.000054" Ni 0.000054"	500	9.0 Pts.

WEARABILITY DATA ON OROTEMP GOLD OVER NICKEL PLATING  
OVER BASIS METAL

2	Au 0.000039" Ni 0.000044"	442	7.5 Pts.
2	Au 0.000045" Ni 0.000092"	442	7.5 Pts.
3	Au 0.000084" Ni 0.000180"	500	7.0 Pts.
2	Au 0.000207" Ni 0.000163"	253	1.5 Pts.
Summary 9	Average Au 0.000093" Ni 0.000127"	Average 430	Average 6.0 Pts.

WEARABILITY DATA ON RHODIUM OVER NICKEL PLATING  
OVER BASIS METAL

1	Rh 0.000045" Ni 0.000165"	500	9.0 Pts.
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WEARABILITY DATA ON OROTEMP GOLD OVER RHODIUM OVER NICKEL  
PLATING OVER BASIS METAL

1	Au 0.000030" Rh 0.000050" Ni 0.000155"	500	4.0 Pts.
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CHART 5

WEARABILITY DATA ON OROSENE GOLD OVER RHODIUM PLATING  
OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
1	Au 0.000045" Rh 0.000056"	347	0.0 Pts.

WEARABILITY DATA ON HARD GOLD OVER SILVER PLATING  
OVER BASIS METAL

1	Au 0.000050" Ag 0.000106"	225	0.0 Pts.
1	Au 0.000055" Ag 0.000209"	208	0.0 Pts.
1	Au 0.000096" Ag 0.000091"	234	0.0 Pts.
2	Au 0.000119" Ag 0.000080"	267	1.5 Pts.
2	Au 0.000142" Ag 0.000098"	354	4.5 Pts.
2	Au 0.000164" Ag 0.000141"	429	5.5 Pts.
Summary 9	Average Au 0.000117" Ag 0.000116"	Average 311	Average 2.6 Pts.

# CHART 5

## WEARABILITY DATA ON OROSENE GOLD OVER SILVER PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
1	Au 0.000052" Ag 0.000100"	208	0.0 Pts.
2	Au 0.000057" Ag 0.000183"	383	1.0 Pts.
2	Au 0.000140" Ag 0.000097"	500	5.5 Pts.
5	Au 0.000175" Ag 0.000188"	500	6.6 Pts.
Summary 10	Average Au 0.000133" Ag 0.000160"	Average 447	Average 4.6 Pts.

## WEARABILITY DATA ON AUTRONEX C GOLD OVER SILVER PLATING OVER BASIS METAL

1	Au 0.000123" Ag 0.000218"	500	6.0 Pts.
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## WEARABILITY DATA ON OROTEMP GOLD OVER SILVER PLATING OVER BASIS METAL

2	Au 0.000056" Ag 0.000193"	238	0.0 Pts.
2	Au 0.000113" Ag 0.000098"	354	2.5 Pts.
3	Au 0.000149" Ag 0.000133"	228	0.3 Pts.
Summary 7	Average Au 0.000112" Ag 0.000126"	Average 266	Average 0.9 Pts.

CHART 5

WEARABILITY DATA ON AUTRONEX N GOLD OVER SILVER PLATING  
OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
2	Au 0.000052" Ag 0.000150"	238	0.0 Pts.
1	Au 0.000097" Ag 0.000048"	500	7.0 Pts.
3	Au 0.000144" Ag 0.000156"	471	6.0 Pts.
2	Au 0.000179" Ag 0.000045"	471	7.5 Pts.
Summary 8	Average Au 0.000124" Ag 0.000114"	Average 357	Average 4.9 Pts.

WEARABILITY DATA ON RHODIUM OVER SILVER PLATING  
OVER BASIS METAL

2	Rh 0.000049" Ag 0.000167"	462	2.5 Pts.
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WEARABILITY DATA ON RHODIUM PLATING OVER BASIS METAL

3	0.000031"	203	2.0 Pts.
1	0.000045"	208	0.0 Pts.
Summary 4	Average 0.000035	Average 204	Average 1.5 Pts.

# CHART 5

## WEARABILITY DATA ON SILVER PLATING OVER BASIS METAL

Number Of Tests	Average Thickness	Average Matings To Complete Test	Average Rating Per Lot
2	0.000040"	150	0.0 Pts.
7	0.000049"	140	0.0 Pts.
3	0.000068"	150	0.0 Pts.
6	0.000102"	98	0.0 Pts.
4	0.000198"	89	0.0 Pts.
1	0.000224"	441	6.0 Pts.
1	0.000284"	441	4.0 Pts.
Summary 24	Average 0.000104"	Average 159	Average 0.4 Pts.

## WEARABILITY DATA ON NICKEL PLATING OVER BASIS METAL

2	0.000093"	255	1.5 Pts.
2	0.000101"	244	3.0 Pts.
3	0.000135"	364	5.0 Pts.
5	0.000197"	367	4.8 Pts.
Summary 12	Average 0.000148"	Average 324	Average 4.0 Pts.

## WEARABILITY DATA ON TIN-NICKEL PLATING OVER BASIS METAL

4	0.000526"	500	8.0 Pts.
1	0.000603"	500	9.0 Pts.
1	0.000736"	500	9.0 Pts.
Summary 6	Average 0.000574"	Average 500	Average 8.8 Pts.

CHART 6

COLLECTIVE WEARABILITY DATA FOR GOLD PLATINGS OVER BASIS METAL

Plating Type	Average Thickness	Number of Tests	Average Matings	Average* Points
Orosene 999 Gold	0.000108"	23	332	3.4
Autronex C Gold	0.000096"	24	332	2.8
Autronex CI Gold	0.000094"	25	202	2.3
Autronex N Gold	0.000080"	23	272	1.6
Hard Gold	0.000109"	26	230	1.5
Orctemp Gold	0.000116"	10	190	1.0
Bright Gold	0.000084"	28	193	0.2
Temperex S Gold	0.000089"	25	180	0.1

\* Reference page 175 for explanation of rating procedure.



CHART 6

COLLECTIVE WEARABILITY DATA FOR GOLD OVER SILVER PLATING COMBINATIONS

Plating Type	Thickness Average		Number of Tests	Average Matings	Average* Points
	Gold	Silver			
Autronex C Gold over Silver	0.000123"	0.000218"	1	500	6.0
Autronex N Gold over Silver	0.000124"	0.000114"	8	357	4.9
Orosene 999 Gold over Silver	0.000133"	0.000160"	10	447	4.6
Hard Gold over Silver	0.000164"	0.000141"	9	311	2.6
Orotemp Gold over Silver	0.000112"	0.000126"	7	266	0.9

\* Reference page 175 for explanation of rating procedure.

CHART 6

COLLECTIVE WEARABILITY DATA FOR GOLD OVER NICKEL PLATING COMBINATIONS

Plating Type	Thickness Average		Number of Tests	Average Matings	Average Points*
	Gold	Nickel			
Autronex N Gold over Nickel	0.000101"	0.000130"	8	500	9.0
Bright Gold over Nickel	0.000045"	0.000057"	3	500	9.0
Autronex CI Gold over Nickel	0.000055"	0.000060"	2	500	9.0
Temperex Gold over Nickel	0.000054"	0.000054"	1	500	9.0
Autronex C Gold over Nickel	0.000087"	0.000150"	4	500	8.8
Orosene 999 Gold over Nickel	0.000117"	0.000119"	12	485	8.3
Hard Gold over Nickel	0.000100"	0.000126"	10	500	7.2
Orotemp Gold over Nickel	0.000093"	0.000127"	9	430	6.0

\* Reference page 175 for explanation of rating procedure.

XIX.

HARDNESS TESTING OF PLATED LAYERS

Included as part of the characteristic tests conducted on the electroplated layers were two individual hardness measurements. These measurements included a Vickers hardness measurement and a Scratch hardness measurement.

After an investigation which included actual Vickers hardness testing, it was found that neither method of hardness measurement could be conducted on the electroplated layers, herein investigated, due to a minimum thickness requirement. A minimum thickness of 0.005" is required for a Vickers or a Scratch hardness test. This was determined through correspondence with Dr. Parker, Technic, Inc., Providence, Rhode Island; Mr. Paul Wallace, Chief Metallurgist, Metallurgical, Inc., Minneapolis, Minnesota; and Dr. Harold J. Read, Professor of Metallurgy at the University of Pennsylvania. Also referenced is the ASM Handbook showing minimum thicknesses of electroplated layers for hardness testing.

Therefore, hardness results are not included in this report. Instead, a wearability test for electroplated layers is included. This test was more functional to our contract work and wearability data often could be interpolated into relative hardness evaluations.

XX.

#### CHEMICAL ANALYSIS OF PLATING BATHS

The purpose of chemically analyzing plating baths is to enable the plater to maintain the proper levels of concentrations of the bath constituents which are depleted during periods of operation. It is necessary to maintain concentrations at fixed levels in order to prevent the plating properties from changing. Usually plating quality is lost when concentrations fall.

Experience has shown that a regular analysis schedule is absolutely essential to the maintenance of quality plating. This schedule must include brighteners and other constituents which are difficult or impractical for the plater to perform. Samples of the baths should be periodically submitted to the vendor for analysis of these constituents. The constituents for which analysis procedures are included herein should be analyzed frequently (usually weekly) by the plater using the applicable methods contained in this section or other methods equally appropriate.

The following methods were selected on the basis of simplicity, accuracy, and equipment required.

Changes and deletions made in the series of chemical analysis procedures reported in earlier engineering progress reports include:

- A. The analysis procedure for gold was changed from a volumetric procedure to a gravimetric procedure. The gravimetric procedure is easier and is subject to fewer interferences than the volumetric procedure.
- B. The analysis for phosphate in gold plating baths and for brightener in HG gold baths were deleted. These analysis are done relatively infrequently and are considered sufficiently difficult and lengthy to be impractical for the average plating department. It is recommended that such analysis should be left to the vendor or professional laboratory.

#### ANALYSIS PROCEDURES

See Table IX for make up and standardization of reagent solutions. All water used for make-up or procedures must be either demineralized or distilled.

## A. Gold Analysis

### 1. Applications

- a. All common gold plating baths including HG #3, Orosene 999, Orotemp 24, Gold Strike, Autronex C, Autronex CI, Autronex N, Temperex X, and Sel-Rex Bright Gold.

### 2. Reagents Required

- a. Conc.  $\text{H}_2\text{SO}_4$
- b. Conc.  $\text{HNO}_3$

### 3. Procedure for Gold

- a. Pipette 10 ml of the bath into a 500 ml Erlenmeyer flask.
- b. Add 25 ml of conc.  $\text{H}_2\text{SO}_4$  and 25 ml of conc.  $\text{HNO}_3$ .
- c. Boil gently for about three hours until all of the precipitated gold has coagulated into dark brown lumps. Add 100 ml of water.
- d. Filter through weighed Gooch crucibles and rinse with 30 ml of water. Wash sides of crucible thoroughly.
- e. Dry crucibles in an oven at  $110^\circ\text{C}$  for 1/2 hour.
- f. Weigh crucibles with gold. Subtract this weight from the tare weight of crucible to obtain weight of gold.
- g. Calculations:  $(\text{grams Gold}) \times (243.4) = \text{Dwts/gal Gold}$

## B. Nickel Analysis

### 1. Applications

- a. Nickel Strike, Nickel Plate

### 2. Reagents Required

- a. 0.0575N EDTA (exactly 21.4 grams of 99.0% Disodium Ethylenedinitrilo-Tetraacetate and 6 grams NaOH in 1 liter). No standardization necessary if accurately weighed.

b.  $1/8$   $\text{NH}_4\text{OH}$  (1 volume conc.  $\text{NH}_4\text{OH}/8$  vol  $\text{H}_2\text{O}$ )

c. Murexide Indicator Tablets. (0.4 mgm)

3. Procedure for Nickel

a. Transfer exactly 5 ml of sample with a pipette to a clean 100 ml volumetric flask and dilute to mark with distilled water. Shake by turning end for end one minute.

b. Add 90 ml of solution containing 10 ml of concentrated ammonium hydroxide and 80 ml water to a 250 Erlenmeyer flask. In this solution, dissolve one 0.4 milligram tablet of Murexide Indicator.

c. Pipette into the ammonium hydroxide solution exactly 5 ml of the diluted sample from (1).

d. From a 50 ml burette, titrate the mixture (3) with standardized 0.0575N EDTA (Disodium Ethylenedinitrilo-tetraacetate) until the first permanent blue color persists with agitation. A noticeable change to blue should occur with the final drop.

e. Record the volume of the EDTA solution and calculate the concentration of nickel in the original solution as metal in the following manner.

f. Calculations:

$$\text{Nickel, oz/gal} = (\text{ml EDTA Titrated}) \times (0.0575 \text{ or Proper Normality}) \times 31.4$$

C. Copper Analysis

1. Applications:

a. Copper Plate (Cyanide Types)

2. Reagents Required

a. 0.1N  $\text{Na}_2\text{S}_2\text{O}_3$  (Standard)

b. Conc.  $\text{H}_2\text{SO}_4$

c. Conc.  $\text{HNO}_3$

- d. Conc.  $\text{NH}_4\text{OH}$
- e.  $\text{NH}_4\text{F} \cdot \text{HF}$  (Ammonium Bi-Fluoride)
- f. 5N Acetic Acid
- g. 20% KI
- h.  $\text{NH}_4\text{CNS}$  (Solid)
- i. Starch Indicator Solution

### 3. Procedure for Copper

- a. Pipette a 5 ml sample into a 250 ml Erlenmeyer flask.
- b. Add 5 ml of sulfuric acid (conc.) and 1 ml of Nitric acid (conc.) while shaking under a hood (HCN gas is evolved).
- c. Boil until dense white sulfur trioxide fumes are evolved, to eliminate all nitric acid. If organic brighteners and/or tartrates are present, use 10 ml of  $\text{H}_2\text{SO}_4$  (conc.) and after first charring and fuming, cool and add an additional 2 ml of  $\text{HNO}_3$  (conc.). Then again fume to whiten the solution.
- d. Cool and add 100 ml of water.
- e. Add  $\text{NH}_4\text{OH}$  (conc.) until the solution is colored dark blue and a definite ammonia odor can be noted.
- f. Boil 15 minutes, or until all excess ammonia has been vaporized as evidenced by lightening of the color.
- g. Add 2 gr of ammonium bi-fluoride and 10 ml of acetic acid (5N) at which point the solution should be light blue in color.
- h. After cooling the solution to room temperature, add 25 ml of potassium iodine (20%) or 2 to 5 grams of KI. Shake.
- i. Titrate with 0.1N sodium thiosulfate solution until the brown color of the sample solution begins to turn yellow.

- j. Add 2 ml of 1% starch solution, 2 gr of ammonium thiocyanate and continue titrating until the blue color disappears and does not return for about one minute.

k. Calculations:

$$\text{Copper, oz/gal} = (\text{ml of Na}_2\text{S}_2\text{O}_3) \times (\text{the Normality of Na}_2\text{S}_2\text{O}_3) \times 1.71$$

Note: During titration, the solution may turn yellow far before the end point is reached. In this case, the titration must be carried as rapidly as possible to completion after the addition of ammonium thiocyanate.

D. Silver Analysis

1. Applications

- a. Silver Plate, Silver Strike

2. Reagents Required

- a. Conc.  $\text{HNO}_3$
- b. Conc.  $\text{H}_2\text{SO}_4$
- c. 0.1N KCNS (Standard)
- d. Ferric Ammonium Sulfate (2%)

3. Procedure for Silver

- a. Pipette (2 ml for Silver Plate, 10 ml for Silver Strike) of bath into a 250 ml Erlenmeyer flask.
- b. Add 20 ml of  $\text{H}_2\text{SO}_4$  (conc.) and 5 ml of nitric acid (conc.) under a hood.
- c. Boil until the white precipitate, which is formed, dissolves and brown fumes cease to evolve.
- d. Cool and slowly add 100 ml of distilled water.
- e. Add 1 ml of ferric ammonium sulfate (2%) and titrate with standard 0.1N potassium thiocyanate to a faint pink color.



f. Calculations:

$$2 \text{ ml Sample Silver, Troy oz/gal} = (\text{ml of KCNS}) \times (\text{Normality})$$

$$10 \text{ ml Sample Silver, Troy oz/gal} = (\text{ml of KCNS}) \times (\text{Normality}) \times (1.45)$$

E. Free Cyanide Analysis as KCN or NaCN

1. Applications

- a. Copper Plate, Silver Plate, Silver Strike, Gold Strike, and Sel-Rex Bright Gold

2. Reagents Required

- a. 0.1N  $\text{AgNO}_3$  (Standard)  
b 10% KI

3. Procedure for Free Cyanide:

- a. Pipette a sample (see chart, page 197) of the bath into a 250 ml Erlenmeyer flask.  
b. Add 75 ml of distilled water and 1 ml of potassium iodide solution (10%).  
c. Titrate with 0.1N standard silver nitrate solution until a faint yellowish turbidity persists after stirring. Maintain rapid stirring during titration.  
d. Calculations:

$$\text{oz/gal} = (\text{ml of AgNO}_3) \times (\text{Normality}) \times (F) \text{ where } F \text{ is factor in the following chart, page 197.}$$

Note: In the case of copper plating baths, the silver tends to be reduced turning the solution dark if the titration is prolonged and stirring inadequate during titration. Consequently, the titration with  $\text{AgNO}_3$  shall be rapid, and vigorous stirring should be employed.

# FACTOR AND SAMPLE SIZE FOR CYANIDE ANALYSIS

For Conc. Range of Bath	0-1 oz/gal	1-4 oz/gal	4-13 oz/gal	13-20 oz/gal
Use Sample Of	10 ml	5 ml	2 ml	1 ml
Factor (F) for KCN	1.74	3.48	8.70	17.4
Factor (F) for NaCN	1.31	2.62	6.55	13.1

## F. Chloride Analysis as $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$

### 1. Applications

- a. Nickel Strike, Nickel Plate

### 2. Reagents Required

- a. 0.1N  $\text{AgNO}_3$  (Standard)
- b. Calcium Carbonate (powder)
- c. 5%  $\text{K}_2\text{CrO}_3$  Indicator

### 3. Procedure for Chloride Analysis

- a. Pipette a 2 ml sample of the bath into a 250 ml Erlenmeyer flask.
- b. Dilute to 100 ml with distilled water, adding a little powdered calcium carbonate (1 gr) if the pH is below 4.0.
- c. Add 3 drops of potassium chromate indicator (5%).
- d. Titrate with standard 0.1N silver nitrate solution until a drop gives a reddish-orange color to the silver chloride precipitate, which does not disappear with stirring.
- e. Calculations

$$\text{Nickel Chloride } .6\text{H}_2\text{O, oz/gal} = \frac{(\text{ml of AgNO}_3) \times (\text{Normality} \times 7.96)}{100}$$

## G. Boric Acid Analysis

### 1. Application

- a. Nickel Plate

### 2. Reagents Required

- a. 0.1N NaOH (Standard)
- b. Saturated Potassium Ferrocyanide
- c. Phenolphthalein Indicator (Powder)
- d. Mannitol

### 3. Procedure for Boric Acid Analysis

- a. Pipette a 2 ml sample into a 250 ml Erlenmeyer flask.
- b. Add 25 ml distilled water and 10 ml of saturated potassium ferrocyanide.
- c. Add 5 grams of mannitol, shake and then add a pinch of phenolphthalein indicator powder.
- d. Titrate with standard NaOH until the color of the solution changes from green to the first permanent change to a redish tint. Record the volume consumed.
- e. Calculations

$$\text{Boric Acid, oz/gal} = (\text{ml of NaOH}) \times (\text{Normality}) \times 4.12$$

## H. Carbonate Analysis as $\text{K}_2\text{CO}_3$ or $\text{Na}_2\text{CO}_3$

### 1. Applications

- a. Silver Plate, Silver Strike, Gold Strike

### 2. Reagents Required

- a. Saturated  $\text{Ba}(\text{NO}_3)_2$
- b. 0.5N Hydrochloric Acid (Standard)
- c. Methyl Orange Indicator (2%)

1. Procedure for  $K_2CO_3$  or  $Na_2CO_3$

- a. Pipette a 10 ml sample into a 250 ml beaker.
- b. Add 100 ml of distilled water and heat to almost boiling.
- c. Add 20 ml of barium nitrate solution (saturated). Allow the precipitate to coagulate.
- d. Filter through Whatman Filter Paper, checking the filtrate with barium nitrate solution for complete precipitation. Wash with three 20 ml portions of hot water, rinsing out the precipitation beaker each time.
- e. Carefully transfer the filter paper containing the washed precipitate to the original beaker and add 50 ml of distilled water plus 3-5 drops of methyl orange indicator (0.2%).
- f. Titrate slowly with standard 0.5N hydrochloric acid until the orange color just becomes pink. Stir during titration with a glass stirring rod, mashing paper.
- g. Calculations

$$\text{Potassium Carbonate, oz/gal} = (\text{ml of HCL}) \times (\text{Normality}) \times (.927)$$

$$\text{Sodium Carbonate, oz/gal} = (\text{ml of HCL}) \times (\text{Normality}) \times (.71)$$

I. Rochelle Salt Analysis

1. Applications

- a. Copper Plate

2. Reagents Required

- a. 0.1N  $Na_2S_2O_3$  (Standard)
- b. 0.1N  $KMnO_4$  (Approx. 0.1N)
- c. KI (Solid)

- d. Starch Indicator
- e. 20%  $\text{H}_2\text{SO}_4$ , 1%  $\text{H}_2\text{SO}_4$
- f.  $\text{MnSO}_4$  (Solid)
- g. 10%  $\text{AgNO}_3$  Sln.
- h. Nitrobenzene
- i. Phenolphthalein Indicator (Powder)

### 3. Procedure for Rochelle Salt

- a. Pipette a 5 ml sample into a 250 ml Erlenmeyer flask.
- b. Add 75 ml of distilled water, a pinch of phenolphthalein powder and 5 ml of nitrobenzene.
- c. Add sulfuric acid (1%) dropwise until the pink color just disappears.
- d. Add silver nitrate solution (10%) dropwise with shaking until no more precipitate forms.
- e. Shake for a minute and add 1 drop of silver nitrate solution (10%) to the clear supernatant liquid to determine whether precipitation of the metal and cyanide is complete. If not complete and precipitate forms, add silver nitrate solution until no further precipitation occurs.
- f. Shake until all precipitate is collected in globule of nitrobenzene. Transfer solution to a 200 ml volumetric flask leaving the precipitate behind. Wash remaining precipitate with 50 ml of water and transfer washing to original solution in volumetric flask.
- g. Dilute the solution to the 200 ml mark in the volumetric flask with water and shake thoroughly.
- h. Pipette out 50 ml of the clean liquid into a 250 ml Erlenmeyer flask.
- i. Add 5 ml of sulfuric acid (20%), 5 gr of manganese sulfate ( $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ ) and 100 ml of water.

- j. Heat to about 170°F and slowly add exactly 20 ml of 0.1N potassium permanganate, while agitating.
- k. Allow to stand 5 minutes then cool under running water.
- l. Add 2 gr of solid potassium iodide and 2 ml of starch indicator solution (1%) and shake.
- m. Titrate with standard 0.1N sodium thiosulfate until the blue color disappears and does not return for at least one minute. Call this titration volume (V).
- n. Repeat steps 9-13 without sample of standardization. Call this titration volume (S).
- o. Calculations

$$\text{Rochelle Salt, oz/gal} = (S-V) \times (\text{Normality of Na}_2\text{S}_2\text{O}_3) \times (5.03)$$

(V and S are titration volumes in milliliters of Steps 13 and 14 respectively)

## TABLE IX

### MAKE-UP - REAGENT SOLUTIONS FOR THE PLATING BATH ANALYSIS

#### A. Standards

##### 1. Standard 0.5N Sodium Hydroxide

- a. Add 20 grams of NaOH AR pellets to 200 ml of water and stir until dissolved.
- b. Pour into a 1 liter volumetric flask and dilute to 1 liter with demineralized or distilled water. Keep bottle tightly stoppered.
- c. Standardization: Dissolve about 2 grams (accurately weighed to .001 gr) of (primary standard) potassium acid phthalate in 100 ml of water in a 250 ml Erlenmeyer flask.
- d. Add 5 drops of phenolphthalein indicator and titrate with the 0.5 N NaOH until red or pink.

$$\text{Exact Normality} = \frac{(\text{grams of potassium acid phthalate})}{(.2042) (\text{Vol. Titrated})}$$

##### 2. Standard 0.1N Sodium Hydroxide

- a. Same as for Standard Solution 1 except that 4 grams of NaOH and 0.4 grams of potassium acid phthalate are used for standardization.

##### 3. Standard 0.1N Hydrochloric Acid

- a. Dilute 8.5 ml of concentrated HCl to 1 liter.
- b. Standardization: Weigh accurately 0.2 gram of dry reagent grade  $\text{Na}_2\text{CO}_3$  and dissolve in 75 ml of water. Add 4 drops of methyl orange indicator (0.2%). Titrate with the HCl solution to the first appearance of an orange-pink color.

$$\text{Exact Normality} = \frac{\text{Grams of Na}_2\text{CO}_3}{(.053) (\text{ml of HCl})}$$

TABLE IX

4. Standard 0.5N Hydrochloric Acid

- a. Same as Standard Solution 3 except that 42.5 ml of concentrated HCl is diluted to 1 liter, and about 1 gram of  $\text{Na}_2\text{CO}_3$  is used for standardization.

5. Standard 0.1N Sodium Thiosulfate

- a. Dissolve 25 grams of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  and 1 gram of NaOH in a little water (50 ml) and dilute to 1 liter.
- b. Standardization: Weigh accurately 3 grams of  $\text{KIO}_3$  (primary standard), dissolve in a little water and dilute to exactly 200 ml. Keep this solution as a primary standard. To standardize, pipette 10 ml of this solution into a 250 ml flask; add 50 ml water, 3 grams of potassium iodide, 5 ml of concentrated  $\text{H}_2\text{SO}_4$ . Titrate with the  $\text{Na}_2\text{S}_2\text{O}_3$  until the solution becomes straw yellow. Add 1 ml of fresh starch indicator and continue titrating to the disappearance of the blue color.

$$\text{Exact Normality} = \frac{(\text{Grams of } \text{KIO}_3 \text{ in the Original 200 ml Standard})}{(.714) (\text{ml of } \text{Na}_2\text{S}_2\text{O}_3)}$$

6. Standard 0.1N Silver Nitrate<sup>9</sup>

- a. Dissolve 17 grams of pure silver nitrate in water and dilute to 1 liter with shaking. Either pure sodium chloride or potassium chloride can serve as the primary standard.
- b. Standardization: The procedure for standardization of the  $\text{AgNO}_3$  against potassium chloride follows:

Dry some reagent potassium chloride at  $110^\circ\text{C}$  and weigh out accurately a sample of it (between 0.25 and 0.30 grams). Dissolve it in 100 ml water and add 6 drops of 5% potassium chromate solution as indicator. Titrate with the silver nitrate solution until an orange-red color persists for 30 seconds.

<sup>9</sup>Foulke, D. G. and Crane, F. D., Electroplaters' Process Control Handbook, 1963, p. 422.



TABLE IX

Calculate the normality as follows:

$$\text{Exact Normality} = \frac{\text{mg of KCl}}{(74.55) (\text{ml of AgNO}_3)}$$

7. Standard 0.1N Potassium Thiocyanate<sup>9</sup>

- a. Dissolve 9.8 grams of pure potassium thiocyanate in water and dilute to 1 liter.
- b. Pipette a 25 ml portion of a standard 0.1N silver nitrate solution into a 250 ml Erlenmeyer flask, and add 5 ml of the ferric ammonium sulfate indicator plus 10 drops of HNO<sub>3</sub> (conc.).
- c. Titrate with the potassium thiocyanate solution to a faint pink color, which is permanent for at least 1 minute. The normality of the KCNS is calculated as follows:

$$\text{Exact Normality} = \frac{(\text{Normality of AgNO}_3) \times 25}{(\text{ml KCNS to Reach End Point})}$$

B. Indicators

1. Methyl Orange

- a. Dissolve 0.2 gram in 100 ml of water.

2. Ferric Ammonium Sulfate (2%)

- a. Dissolve 2 grams of solid ferric ammonium sulfate in 75 ml of warm distilled water. Filter and dilute to 100 ml.

3. Potassium Chromate (5%)

- a. Dissolve 5 grams of solid potassium chromate in 100 ml of water.

4. Phenolphthalein Indicator.

- a. Dissolve 0.1 gram of solid phenolphthalein in 100 ml ethyl alcohol and dilute with water to 500 ml.

<sup>9</sup>Foulke, D. G. and Crane, F. D., Electroplaters' Process Control Handbook, 1963, p. 422.

TABLE IX

5. Potassium Iodide (10%)
  - a. Dissolve 10 grams KI in 90 ml of water.
6. Starch Indicator (1%)
  - a. Make a slurry consisting of 1 gram of soluble starch and 3 ml of water. Pour this slurry into 100 ml of boiling water and stir.

C. Non-Standard Reagents

1. Acetic Acid 5N
  - a. Mix 100 ml of concentrated acetic acid (glacial) with 260 ml of water.
2. Sulfuric Acid (20%)
  - a. Mix 30 ml of concentrated  $H_2SO_4$  with 190 ml of water.
3. Sodium Hydroxide (20%)
  - a. Dissolve 40 grams of sodium hydroxide pellets into 170 ml of water. Do not mix in thick glass bottle because much heat is liberated.
4. Sodium Chloride (5%)
  - a. Dissolve 10 grams of solid sodium chloride in 200 ml of water.
5. Silver Nitrate (10%)
  - a. Dissolve 20 grams of solid silver nitrate in 200 ml of water.
6. Barium Nitrate (Saturated)
  - a. Add enough solid barium nitrate to water in order that some solid remains undissolved after 3 hours of stirring.
7. Potassium Ferrocyanide (Saturated)
  - a. Stir the solid potassium ferrocyanide into water until no more dissolves.

TABLE IX

8. Quinoline Hydrochloride<sup>10</sup>

- a. Add 20 ml of redistilled quinoline to 800 ml of water to which has been added 20 ml of concentrated hydrochloric acid.
- b. Cool, add paper pulp, shake well and filter under suction.
- c. Make up the filtrate to 1 liter.

9. Potassium Iodide (30%)

- a. Dissolve 60 grams of the solid potassium iodide in 200 ml of water.

<sup>10</sup>"Analysis of Electroplating and Related Solutions" by:  
K. E. Langford, Note #2, p. 263.

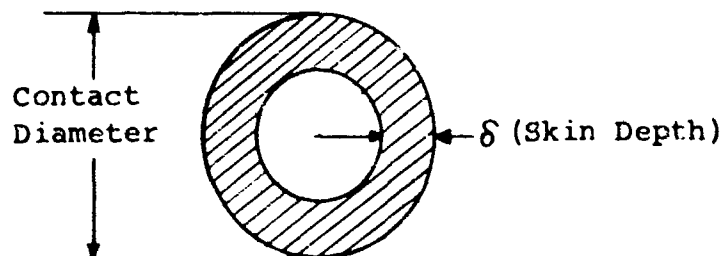
XXI.

ELECTROPLATING AND ITS RESULTS ON SKIN EFFECT PHENOMENA

It is the purpose of this section to evaluate the extent of the skin effect phenomena on MIL-C-26636 contacts when used in MIL-C-26500 connector applications. This effect was evaluated for connectors carrying currents at frequencies below the RF range, which limited the study to frequencies under 20,000 cycles. The effect of electroplating on skin effect (electrical), was determined for various contact materials.

In conductors carrying alternating currents, electromotive forces are induced which vary in magnitude across the cross section of the conductor. They are greater at the center than at the surface, thus creating a potential difference from inside to outside, thereby decreasing the effective current-carrying area of the conductor. This then increases the total resistance and decreases the current capacity. As this potential difference increases, the current is forced further to the outside until the outer-most portion of the conductor is carrying the bulk of the current. This is "Skin Effect."

One way of expressing the magnitude of skin effect is to determine to what extent the current has been forced to the outside of the conductor. For wires, tubes and other compact shapes, the conductor can be approximately replaced by a cylindrical shell of wall thickness  $\delta$ . This "Skin Depth" is the distance below the surface where the current density value has been reduced to  $1/e$  or 36.75% of its value at the surface. The Cylinder has a uniform current density equal to that at the surface of the actual conductor, carries the total current load, and has the effective resistance of the conductor.



The skin depth can be calculated by the following equation.<sup>11</sup>

$$\delta = \frac{1}{2\pi} \sqrt{\frac{\rho \times 10^3}{f}} \quad \text{Centimeters}$$

Where:  $\rho$  is the volume resistivity of the contact material in microhm-cm,  $f$  is the frequency in cycles per second.

Since the skin depth decreases as the frequency increases, all calculations of  $\delta$  will be made with  $f = 20,000$  cycles. This will result in the most severe skin effect to be encountered with MIL-C-26500 connectors, when operated below RF frequencies. For numerical computations, the skin depth can be calculated with:

$$\delta = 0.0140 \sqrt{\rho} \quad \text{Inches}$$

MEASURED VALUES OF VOLUME RESISTIVITY  
MICROHM-CM

Leaded Copper	1.74	Nickel Silver	30.75
Tellurium Copper	1.79	Nickel Iron	45.00
Chrome Copper	1.82	Silver	1.63
Leaded Brass	7.69	Gold	2.42
Beryllium Copper	10.78	Rhodium	4.51
Phosphor Bronze	10.80	Nickel	7.04
		Tin-Nickel	140.00

SKIN DEPTH CALCULATIONS FOR LEADED COPPER

$$\delta = 0.0140 \sqrt{\rho}$$

$$\delta = 0.0140 \sqrt{1.74}$$

$$\delta = 0.0185 \text{ Inches}$$

Values of Skin Depth for Eight Typical Contact Materials at a frequency of 20,000 cycles:

Leaded Copper	0.0185 in.	Beryllium Copper	0.0458 in.
Tellurium Copper	0.0188 in.	Phosphor Bronze	0.0458 in.
Chrome Copper	0.0189 in.	Nickel Silver	0.0778 in.
Leaded Brass	0.0388 in.	Nickel Iron	0.0940 in.

<sup>11</sup>Standard Handbook for Electrical Engineers, Ninth Edition, 1957.

The combination of a leaded copper contact, and a frequency value of 20,000 cycles provides the most severe skin effect that MIL-C-26500 connectors should encounter if they are applied within their design recommendations. For leaded copper contacts the current is essentially carried in the outer 0.0185 inches of the contact. For size #12 contacts this represents 62½% of the total cross sectional area. For size #16 contacts it is 83% and it is 99% of the total area for size #20 contacts.

Consider how the skin effect is varied by the addition of a plated layer or layers of suitable metals. Since silver is the best known conductor it should be the most beneficial in helping carry the added current load in the hypothetical cylinder of wall thickness  $\delta$ . The extent of this improvement can be determined by evaluating the change in the effective volume resistivity of the combination of metals compared to that of the leaded copper without plating. If the effective resistivity is decreased by plating, the total current carrying ability of the contact will be increased.

A 0.000200 inch thick silver over basis metal was one of the plates recommended during the User Survey portion of this program, and will be used here for calculating the change in resistivity due to plating. The effective volume resistivity ( $\rho_p$ ) of an 0.000200 inch silver ( $\rho_{Ag} = 1.63$  microhm-cm) plated leaded copper ( $\rho_c = 1.74$  microhm-cm) cylinder of thickness 0.0185 inches is given by:

$$\frac{1}{\rho_p} = \frac{1}{94} \left( \frac{1}{1.63} \right) + \frac{93}{94} \left( \frac{1}{1.74} \right) = .57512$$

$$\rho_p = 1.738 \text{ Microhm-Cm}$$

The effect of the silver plating (0.1% decrease in  $\delta$ ) is so small that it is less than the error limits of the calculation.

When the skin depths for the various contacts are compared with the dimensions of the contacts themselves, they do not have much practical value because they represent such a large portion of the total contact area. In many cases the skin depth is larger than the contacts in question. These of course are meaningless when considered individually, but they do indicate in general that these contacts are operated in a range that is not even close to requiring skin effect considerations. Although meaningless for practical use, the larger values are listed to indicate how far from skin effect problems these contacts actually are.

It should also be pointed out that the skin depth formula only applies when the contact size is at least three times the skin depth. This does not however indicate that another formula should be used, but rather that when values of skin depth exceed this that skin effect is negligible. The calculation of the effect of plating was meant to bear this out even further. When a nominal thickness of silver is added to a contact, and the increase in conductivity of the skin depth is only 0.1% then the use of plating for optimizing the situation has no application.

### CALCULATION OF SKIN EFFECT

The purpose of this chart is to show the effect of the plated layers on the penetration depth characterizing "skin effect" .... This data applies to #12 contacts at a frequency of 20,000 cps. All data was calculated from previously known values of resistivity for both the basis and plate metals.

1. The formula used for calculation of the basis metal (without plating) was that taken from the "Electrical Engineers Handbook," Ninth Edition, page 58.

$$\text{Basic Formula: } \delta = \frac{1}{2\pi} \sqrt{\frac{\rho' \times 10^9}{f}}$$

$\delta$  - Penetration Depth in (Centimeters)

$\rho$  - Volume Resistivity of Contact Material in (Ohm-Cm)

$f$  - Frequency in (Cycles per Second)

For  $f = 20,000$  cps:  $\delta = .014\sqrt{\rho}$  where  $\delta$  is penetration depth in (Inches) and  $\rho$  is in (micro ohm-Cm).

Notes: The top horizontal row lists the penetration depths calculated by means of the basic formula ( $\delta = \sqrt{.014}$ ) The penetration depths for nickel silver and nickel iron are .078" and .094" respectively; they exceed the radius (.047") of the #12 contact. Due to the above, there could not be any skin effect with contacts made of nickel silver or nickel iron basis metals even with the addition of plating. Thus skin effect data for these two metals is not shown herein.

In order that the formula for penetration depth be applicable to this work,  $\delta$  must be small in comparison to R (radius of contacts). The fact that  $\delta$  is

not small in comparison to R at 20,000 cps. is sufficient to conclude that the skin effect is small and unimportant for applications using 20,000 cps. or less. Nevertheless, the calculations employing this formula serve to illustrate that the effect of the plating on skin effect is very small.

2. The percent change in penetration depth can be calculated quite readily by the following procedure.

Basic Formula:  $\delta = .014\sqrt{\rho}$

Differentiate:  $d\delta = .014 \frac{\rho^{-1/2}}{2} d\rho$

For Small Changes:  $\Delta\delta = .014 \frac{\rho^{-1/2}}{2} \Delta\rho$

Divide by Basic Formula:  $\frac{\Delta\delta}{\delta} = .014 \frac{\rho^{-1/2}}{2} \Delta\rho \div .014\sqrt{\rho}$

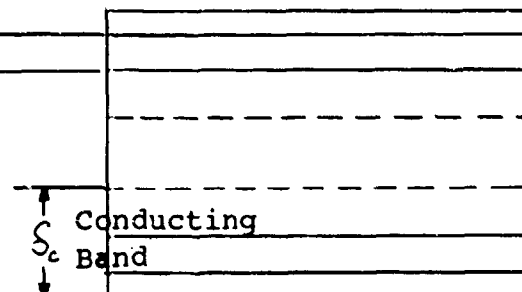
$$\frac{\Delta\delta}{\delta} = \frac{1}{2} \left[ \frac{\Delta\rho}{\rho} \right]$$

$\delta_c$  &  $\rho_c$  are values after plating  
and  $\rho = \rho_c$

Calculate:  $\frac{\Delta\rho}{\rho_c}$  :

Plate (1)  
Plate (2)

Diagram:



In the diagram, we treat the three conducting layers in the conducting band as three (3) parallel conductors [Basis Metal (b), Plate (1), and Plate (2)].

Resistivity Formula:  $\frac{A_c}{\rho_c} = \frac{A_b}{\rho_b} + \frac{A_1}{\rho_1} + \frac{A_2}{\rho_2}$

$A_b$  - Cross sectional area of basis metal in conducting zone.

$A_1$  - Cross Sectional area of plate (1) etc.

Substitute:  $\frac{A_p}{\rho_p} = \frac{A_1}{\rho_1} + \frac{A_2}{\rho_2}$

$$\frac{A_c}{\rho_c} = \frac{A_b}{\rho_b} + \frac{A_p}{\rho_p}$$



Divide by  $A_c$ :  $\frac{l}{e_c} = \frac{A_b}{A_c} \left( \frac{l}{e_b} \right) + \frac{A_p}{A_c} \left( \frac{l}{e_p} \right)$

Substitute:  $A_b = A_c - A_p$

$$\frac{l}{e_c} = \frac{A_c - A_p}{A_c} \left( \frac{l}{e_b} \right) + \frac{A_p}{A_c} \left( \frac{l}{e_p} \right)$$

or:  $\frac{l}{e_c} = \frac{A_p}{A_c} \left( \frac{l}{e_p} - \frac{l}{e_b} \right) + \frac{l}{e_b}$

Subtract:  $\frac{l}{e_b} - \frac{l}{e_c} = \frac{A_p}{A_c} \left( \frac{l}{e_b} - \frac{l}{e_p} \right)$

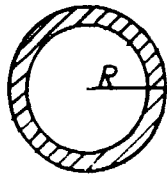
but:  $\frac{l}{e_b} - \frac{l}{e_c} = \frac{e_c - e_b}{e_b e_c} = \frac{\Delta e}{e_b e_c} = \frac{A_p}{A_c} \left( \frac{l}{e_b} - \frac{l}{e_p} \right)$

Multiply by  $e_b$  :  $\frac{\Delta e}{e_c} = \frac{A_p}{A_c} \left( 1 - \frac{e_b}{e_p} \right)$

$A_p$  is the total cross sectional area of plated layers.

$A_c$  is calculated from the unplated penetration depth ( $\delta$ ).

$$A_c = \pi R^2 - \pi(R - \delta)^2 = \pi(2R\delta - \delta^2)$$



$R = .047''$  (Radius of Contact)

Note: Using unplated penetration depth  $\delta$  to calculate  $A_c$  introduces an error of second order in magnitude, and can be neglected in the cases considered.

$e_p$  was calculated using formula:

$$\frac{l}{e_p} = \frac{A_1}{A_p} \left( \frac{l}{e_1} \right) + \frac{A_2}{A_p} \left( \frac{l}{e_2} \right)$$

$$A_p = A_1 + A_2$$

$e_b, e_1, e_2$  are known.

$A_b, A_1$ , and  $A_2$  can be calculated from known thicknesses of platings.

Final Formula Employed:

$$\begin{array}{l} \text{\% relative change in} \\ \text{penetration depth} \end{array} = \frac{100}{2} \left( \frac{A_p}{A_c} \right) \left( 1 - \frac{\rho_b}{\rho_p} \right)$$

Sample Calculation:

For 200 Au/100 Ni/(Be Cu Base)  
Thickness in  $10^{-6}$  Inches.

$$\rho_{Au} = 2.42 \mu \text{ ohm-cm}, \delta = .014 \sqrt{10.78} = .0458 \text{ inches (BeCu)}$$

$$\rho_{Ni} = 7.04 \mu \text{ ohm-cm}$$

$$\rho_b = 10.78 \mu \text{ ohm-cm}$$

$$R = .047 \text{ inches}, A_c = \pi(2R\delta - \delta)^2$$

$$A_c = \pi 2[.047](.0458) - (.0458)^2]$$

$$A_c = 6.94 \times 10^{-3} \text{ sq. in.}$$

$$A_p = (200 + 100) \times 10^{-6} 2\pi(.047 \text{ in}) \text{ sq. in.}$$

$$A_p = 8.87 \times 10^{-5} \text{ sq. in.}$$

$$\frac{1}{\rho_p} = \left( \frac{200}{300} \right) \left( \frac{1}{2.42} \right) + \left( \frac{100}{300} \right) \left( \frac{1}{7.04} \right) = .323$$

$$\frac{\rho_b}{\rho_p} = (10.78)(.323) = 3.47$$

$$\% \text{ Relative Change} = \frac{100}{2} \left( \frac{8.87 \times 10^{-5}}{6.94 \times 10^{-3}} \right) (1 - 3.47) = -1.59 \%$$

CHART 7

SKIN EFFECT DATA

(Percent Change in Penetration Depth Due to Plating)

		Pb Cu	P BRZ	Cr Cu	Be Cu	Pb Br	Te Cu
Base Metal Penetration Depth (at 20 cps.) (Without Plating)		.0185"	.0458"	.0189"	.0458"	.0388"	.0188"
Plating Combination	Thickness In $10^{-6}$ Inches	Percent Change Due to Plating					
Ag/b	50/b	- .01	- .60	- .02	- .60	- .41	- .02
Ag/b	100/b	- .02	-1.20	- .04	-1.20	- .82	- .03
Ag/b	200/b	- .05	-2.39	- .08	-2.39	-1.63	- .07
Au/Ag/b	50/100/b	+ .03	-1.56	-.005	-1.56	-1.05	+ .02
Au/Ag/b	150/100/b	+ .12	-2.33	+ .08	-2.33	-1.54	+ .10
Au/Ag/b	50/200/b	0	-2.76	- .04	-2.76	-1.88	- .03
Au/Ag/b	150/200/b	+ .09	-3.51	+ .04	-3.51	-2.36	+ .05
Au/Ni/b	50/100/b	+ .30	- .48	+ .29	- .48	- .26	+ .29
Au/Ni/b	100/100/b	- .35	- .85	+ .33	- .85	- .50	+ .37
Au/Ni/b	200/100/b	+ .44	-1.59	+ .41	-1.59	- .98	+ .42
Au/Ni/b	50/200/b	+ .55	- .59	+ .53	- .59	- .28	+ .54
Au/Ni/b	100/200/b	+ .60	- .96	+ .58	- .96	- .52	+ .58
Au/Ni/b	200/200/b	+ .70	-1.69	+ .66	-1.69	-1.00	+ .67
Au/b	100/b	+ .94	- .74	+ .08	- .74	- .48	+ .09
Au/b	200/b	+ .19	-1.47	+ .17	-1.47	- .96	+ .17
Sn Ni/b	500/b	+1.66	+ .99	+1.64	+ .99	+1.04	+1.64

CHART 7

SKIN EFFECT DATA

(Percent Change in Penetration Depth Due to Plating)

		Pb Cu	P BRZ	Cr Cu	Be Cu	Pb Br	Te Cu
Base Metal Penetration Depth (at 20 cps.) (Without Plating)		.0185"	.0458"	.0189"	.0458"	.0388"	.0188"
<u>Plating Combination</u>	<u>Thickness In 10<sup>-6</sup> Inches</u>	<u>Percent Change Due to Plating</u>					
Rh/Ag/b	50/150/b	+ .07	-1.94	+ .04	-1.94	-1.31	+ .05
Rh/Ni/b	50/150/b	+ .48	- .32	+ .47	- .32	-1.08	+ .47
Au/Rh/Ni/b	30/50/150/b	+ .51	- .53	+ .49	- .53	- .25	+ .49
Au = Gold Ni = Nickel Rh = Rhodium Ag = Silver Sn = Tin b = Base Metal							

XXII.

### GRAIN STRUCTURE

The nature of the work performed within this section was to investigate and show the variations which exist in grain structure and for different metals, for different conditions of the same metal, and for different locations on the same sample.

Plasticity in a metal is largely determined by the existing grain structure. See Section XI, page 118, for information on the importance of plasticity for good contact crimping.

Grain structure also affects the surface finish resulting from chemical action on metal parts. This includes the cleaning, pickling, bright dipping, and chemical polishing steps which are required for plating processes.

Basis metal grain structure is also important to this work in that it affects the structure of an electrodeposit applied on the basis metal<sup>12</sup>. Internal stress of the deposit and coverage can be influenced by grain structure of the substrate<sup>13</sup>.

Significant variations in grain structure and size can result from operations to which typical contacts are exposed during manufacture. Examples of these conditions are shown in the photomicrographs of grain structure. The photomicrographs on page 216 are of contacts procured to MIL-C-26636. The basis metal is tellurium copper. Note the substantial difference in grain size between the crimp barrel wall and the central section.

The structures on page 217 show the work hardened crimp barrel wall on a leaded copper test part in comparison to the central section of the part. Also shown is the annealing effect resulting from a heat cycle of 460°F for 24 hours. Note the larger and more defined grains in the heated test part.

The fourth photograph (800X) on page 217 shows an abrupt change in grain size within a confined area (approximately .005" across total view in photomicrograph). This is in the crimped area of an annealed (RB 21-27) leaded copper sample.

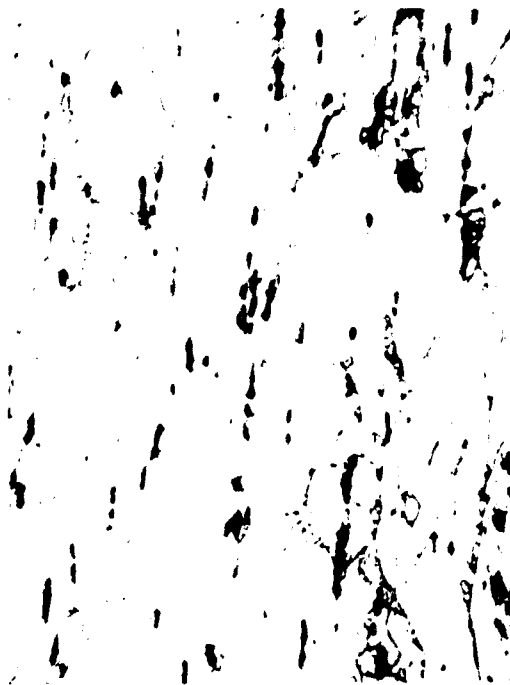
<sup>12</sup>Kushner, Joseph B., "Stress in Electroplated Metals," Metal Progress, 1962, p. 88.

Mohler, J. E. and Sedusky, H. J., Electroplating, 1951.

GRAIN STRUCTURE PHOTOMICROGRAPHS



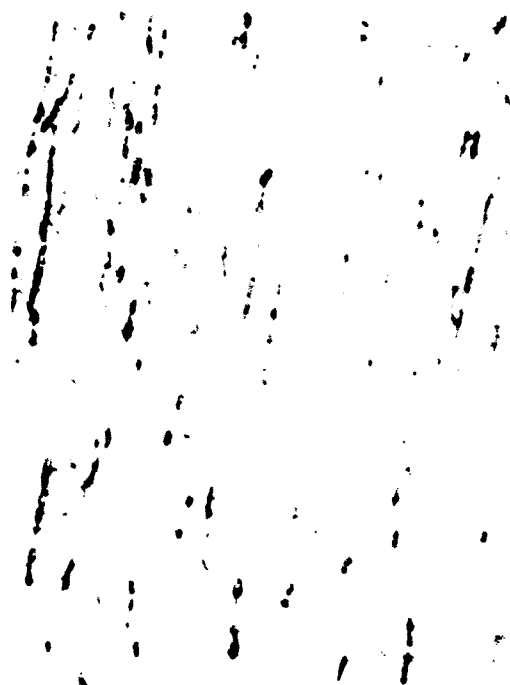
Procured Contact per  
MIL-C-26636 (400X)  
Crimp Barrel



Procured Contact per  
MIL-C-26636 (400X)  
Central Section

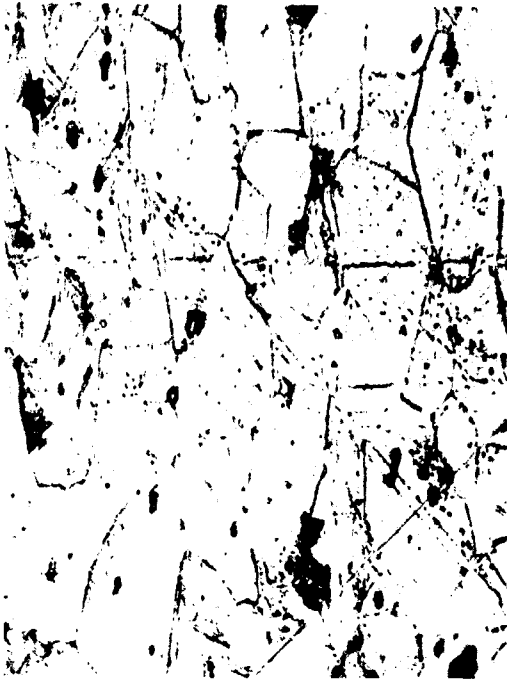


Procured Contact per  
MIL-C-26636 (400X)  
After Heat Test of  
24 Hours at 460° F.  
Crimp Barrel



Procured Contact per  
MIL-C-26636 (400X)  
After Heat Test of  
24 Hours at 460° F.  
Central Section

# GRAIN STRUCTURE PHOTOMICROGRAPHS



Leaded Copper (400X)  
Full Hard  
Crimp Barrel



Leaded Copper (400X)  
Full Hard  
Central Section



Leaded Copper (400X)  
After Heat Aging 24  
Hours at 460° F.  
Central Section



Leaded Copper (800X)  
Crimp Area Showing Abrupt  
Change in Grain Size

XXIII.

## PHOTOMICROGRAPHS

### A. Surface Photomicrographs

The three basic objectives of including photomicrographs are to:

1. Illustrate the differences, if any, in the surface appearance of platings having different quality assurance levels.
2. To illustrate the effect, if any, of underlying or barrier layers on the surface that exist between surfaces of the various types of plating.
3. To demonstrate the differences in appearance that exist between surfaces of the various types of plating.

Platings were therefore chosen on the basis of the type of plating or plating combinations, or on the particular quality assurance rating obtained from that layer for photomicrographs.

### Selection of Parts to be Photographed

All parts photographed were plated on leaded brass flat stock due to the fact that round parts presented an illumination and focus problem. Several parts from each load selected for photomicrographs were examined under high magnification to be assured that we photographed a representative area for that type of plating. Emphasis was made on showing typical or unusual plating characteristics and when possible, to show various quality levels for particular type platings.

### Method of Photography

All of the photographs were taken using the Model U-11 Uni-tron Metallograph with a Polaroid Land Camera Attachment. Tungsten illumination without the use of filters was used for all the photographs. The lamp current was maintained at 4.0 amps. The exposure for each picture was adjusted by means of the lamp iris and the time exposure. In each case the exposure was adjusted to obtain a clear picture at the normal level of brightness. 3000 speed/type 47 black and white polaroid film was used.



Unless otherwise stated, all of the surface photographs were taken with a magnification of 67 power on flat stock parts placed nearly longitudinally with respect to the photograph. The photographs represented on pages 221 and 222 were reduced by 50% when converted to the printed page. These prints are presently at a magnification of approximately 33 power. The photographs represented on pages 223 and 224 were not reduced and are at 67 power. The microsection photographs on these same pages were taken with a magnification of about 750 power. Each subdivision on the superimposed scale represents .0000985 inches of the subject.

#### Discussion of Photographs

The photomicrographs shown on pages 221 through 225 are organized for ease in making comparisons between various quality assurance levels of the referenced types of plating. It is possible here to compare types of plating one to another; optimum, medium, and low levels of plating, physical characteristics, effects of parameter levels and thickness on the quality plating, and to compare porosity and final quality assurance ratings for both plating combinations and single plated layers.

The following is an outline of the pattern for which the photomicrographs were laid out. The horizontal rows, top to bottom are; row (1) Autronex Gold platings; row (2) Orosene 999 Gold platings; row (3) HG Gold platings; and row (4) Orotemp Gold platings. The vertical columns left to right are based on the following: Columns (1) and (2) show interesting correlations for points shown on Graph 14, page 172, of Porosity -vs- Thickness for all gold platings. Note that in comparing points in column (1) to points in column (2) the platings are nearly similar, however, they fall in different areas of the graph. Column (3) shows interesting results obtained from plating combinations with relatively thin nickel barrier layers. Note the high quality assurance results in spite of what type of gold that was plated. Column (5) shows interesting results obtained from plating combinations with relatively thin gold over thick silver plating. Note the poor quality assurance results obtained. Column (6) shows interesting results obtained from plating combinations with relatively thin gold over thin silver plating. Note also the poor quality assurance results obtained.

The outer most light band seen in the microsections is a heavy nickel plating which was applied to provide the sheath necessary for microsectioning. The very narrow dark line which separates this layer from the functional layer is a copper strike applied in order to locate the boundary of the functional layer.

It should be noted here that one can observe optimum, medium, and low levels of plating for gold alone or in combination with a barrier plated metal by referencing the quality assurance rating shown under the photomicrograph. A rating of 11 or higher is considered a quality plating.

All references to thickness in the following photomicrographs are in millionths of an inch.

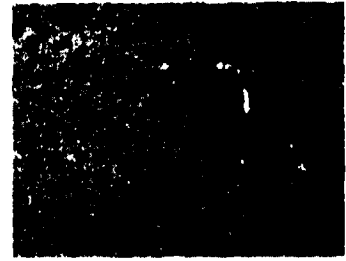
# PHOTOMICROGRAPHS OF



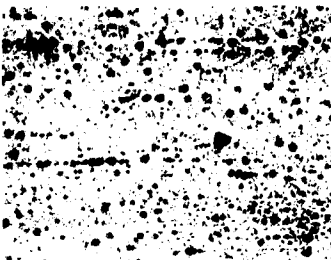
Test #10 (33X)  
Autronex Gold/Base  
F. Rating 10.0 pts.



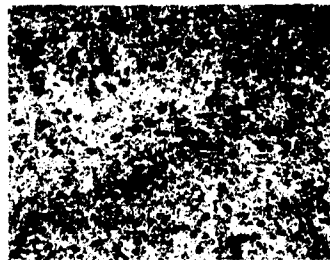
Test #38 (33X)  
Autronex Gold/Base  
F. Rating 7.66 pts.



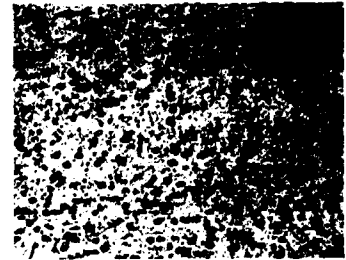
Test #76 (33X)  
Autronex Gold/Nickel  
F. Rating 14.0 pts.



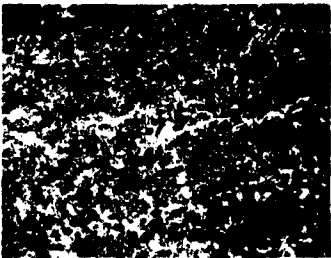
Test #46 (33X)  
Orosene Gold/Base  
F. Rating 9.23 pts.



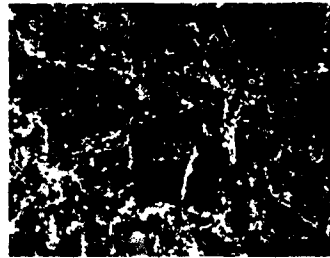
Test #42 (33X)  
Orosene Gold/Base  
F. Rating 13.0 pts.



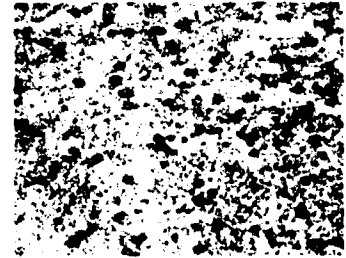
Test #88 (33X)  
Orosene Gold/Nickel  
F. Rating 16.0 pts.



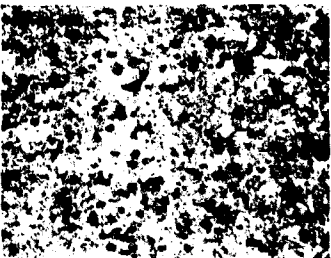
Test #33 (33X)  
HG Gold/Base  
F. Rating 7.93 pts.



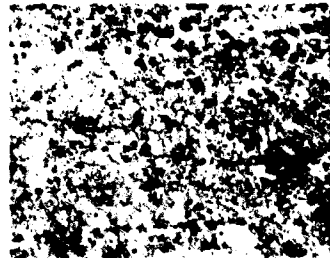
Test #31 (33X)  
HG Gold/Base  
F. Rating 9.01 pts.



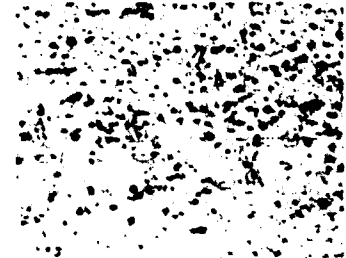
Test #70 (33X)  
HG Gold/Nickel  
F. Rating 13.0 pts.



Test #13 (33X)  
Orotemp Gold/Base  
F. Rating 6.27 pts.

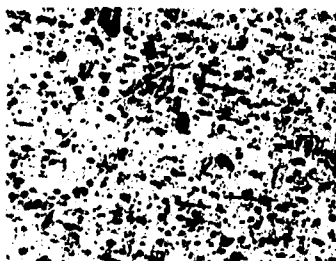


Test #40 (33X)  
Orotemp Gold/Base  
F. Rating 6.16 pts.



Test #82 (33X)  
Orotemp Gold/Nickel  
F. Rating 14.0 pts.

# CHARACTERISTIC PLATINGS



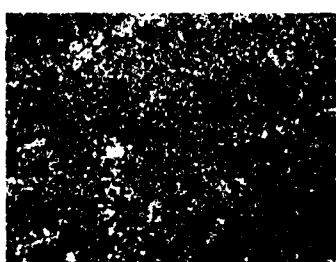
Test #58 (33X)  
Autronex Gold/Silver  
F. Rating 13.0 pts.



Test #59 (33X)  
Autronex Gold/Silver  
F. Rating 5.88 pts.



Test #57 (33X)  
Autronex Gold/Silver  
F. Rating 8.34 pts.



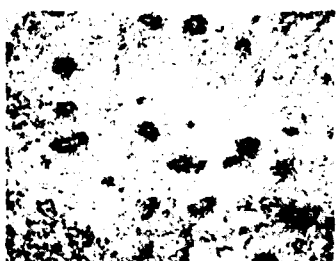
Test #66 (33X)  
Orosene Gold/Silver  
F. Rating 14.0 pts.



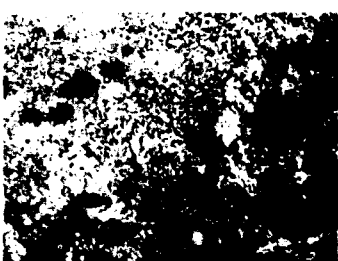
Test #67 (33X)  
Orosene Gold/Silver  
F. Rating 8.11 pts.



Test #65 (33X)  
Orosene Gold/Silver  
F. Rating 6.95 pts.



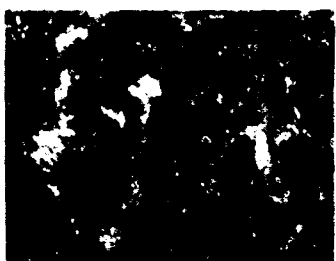
Test #54 (33X)  
HG Gold/Silver  
F. Rating 12.0 pts.



Test #55 (33X)  
HG Gold/Silver  
F. Rating 4.92 pts.



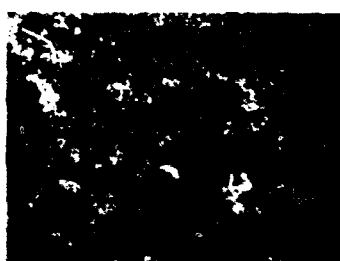
Test #53 (33X)  
HG Gold/Silver  
F. Rating 6.75 pts.



Test #62 (33X)  
Orotemp Gold/Silver  
F. Rating 15.0 pts.

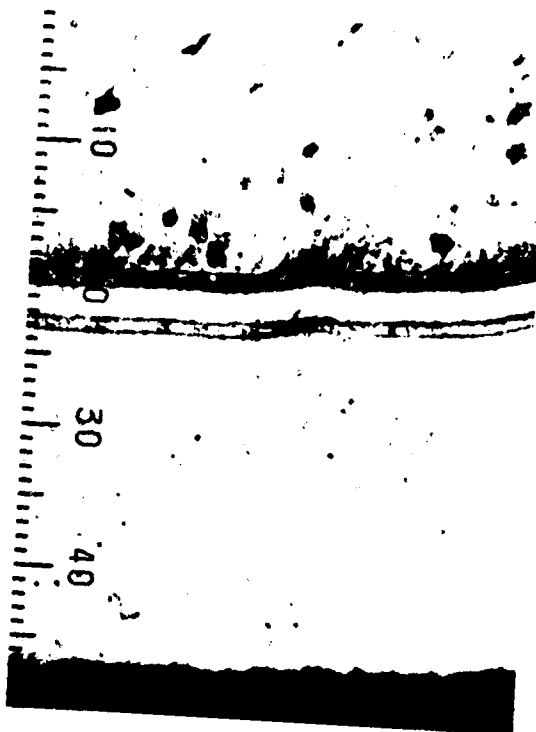


Test #63 (33X)  
Orotemp Gold/Silver  
F. Rating 6.28 pts.



Test #61 (33X)  
Orotemp Gold/Silver  
F. Rating 6.28 pts.

# PHOTOMICROGRAPHS OF SILVER PLATING



Microsection (Test #2-A)  
Optimum Plating (750X)



Surface (Test #2-A)  
Optimum Plating (67X)

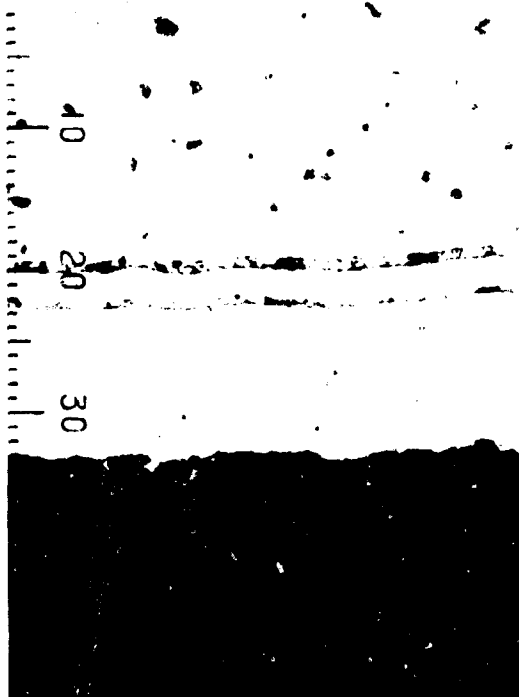


Surface (Test #2)  
Medium Plating (67X)



Surface (Test #1)  
Poor Plating (67X)

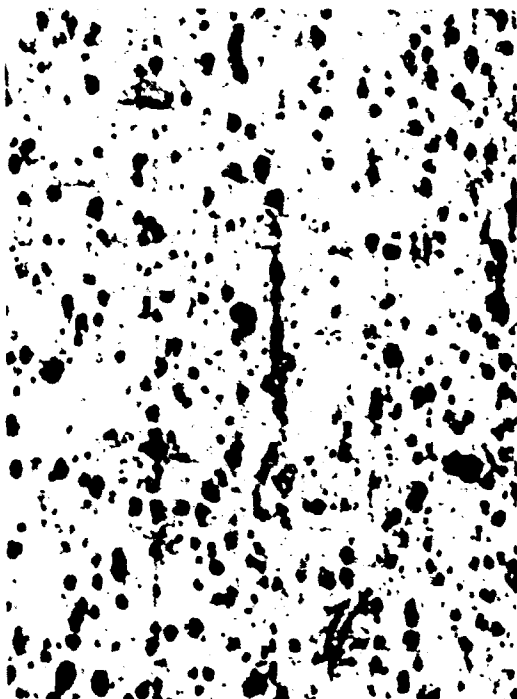
# PHOTOMICROGRAPHS OF NICKEL PLATING



Microsection (Test #49)  
Optimum Plating (750X)



Surface (Test #49)  
Optimum Plating (67X)



Surface (Test #25)  
Medium Plating (67X)

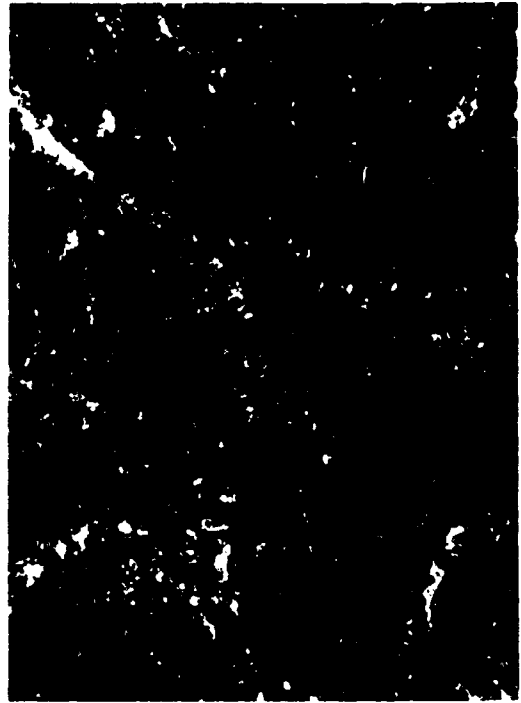


Surface (Test #47)  
Poorer Plating (67X)

PHOTOMICROGRAPHS OF TIN-NICKEL AND RHODIUM PLATINGS



Surface (Test #21) (67X)  
Rhodium/Leaded Brass 51/B  
Quality Assurance Rating (2)



Surface (Test #69) (67X)  
Rhodium/Silver/Leaded Brass  
37/183  
Quality Assurance Rating (9.2)



Surface (Test #105) (67X)  
Tin-Nickel/Leaded Brass 271/B  
Quality Assurance Rating 10.1



Surface (Test #107) (67X)  
Tin-Nickel/Leaded Brass 282/B  
Quality Assurance Rating (8.46)

## B. Photomicrographs of Industrial Plating Problems

The following pictures, page 229, are photomicrographs taken at Nu-Line Industries of actual plated contacts. These photographs are not pictures of work done as part of the contract but are pictures taken by our Electroplating Inspection Department to show particular characteristics of given production contacts after they have been electroplated and inspected. These photographs are included here to better exemplify the need for quality assurance and to clearly show typical characteristics of plating pertinent to this work.

Photograph #1 is an example of what can happen when a burr is left from machining. As shown by the arrows the burr that remained after plating formed a small cavity. The contact was first nickel and then gold plated. The nickel plated both inside and outside of this burr until the opening to the cavity had been completely closed due to nickel plating. The result was an incapsulated cavity that could cause extensive trouble if not found and the part discarded. First, this cavity could trap plating solution whereby later in the field this cavity would probably start to bleed. Second, this burr has caused a nodule that could create galling if brought in contact with another metal surface. Third, if this nodule is punctured it would make an ideal spot for corrosion to begin.

Photograph #2 was taken of a set of burrs entrapped between two tines of a contact. These burrs were so tiny that they were not discovered until the part was microsectioned for inspection of plating. The outside edge of the two sides of the picture are the actual contact walls. This picture exemplifies a typical problem that might have been avoided by proper cleaning methods. For this particular problem that might include ultrasonic cleaning or strong etching.

Photograph #3 shows the result of a scratch that occurred on the end of a gold plated contact. Note the decreased corrosion resistance afforded this contact due to the thin layer of gold at the bottom of the scratch. Also note the furrow effect with the mounds of gold on each side.

Photograph #4 is of a gold plated contact that had nodules on the surface of the gold. The first plated layer is a copper strike, the second layer is the gold, the third, very thin layer, is a copper strike so that the part could be nickel plated for microsectioning.

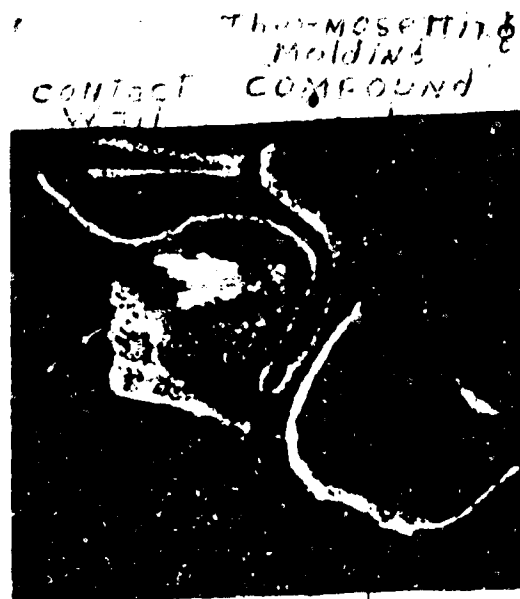


Note the sub layers below the gold are basically smooth and the surface of the nickel over the nodules is smooth. This shows that one can get nodules even if the basis metal is smooth and it also shows the leveling effect of nickel plating. As background information relative to this part we were experiencing a nodule problem at the time the photomicrograph was taken with one of our gold baths. This problem was eliminated by special filtration before plating, decreasing current density, and by removing gold nodules from the dangles in the tumbler. These nodules would break off the dangles and fall onto the parts, sticking there, and then they would be plated right on the part.

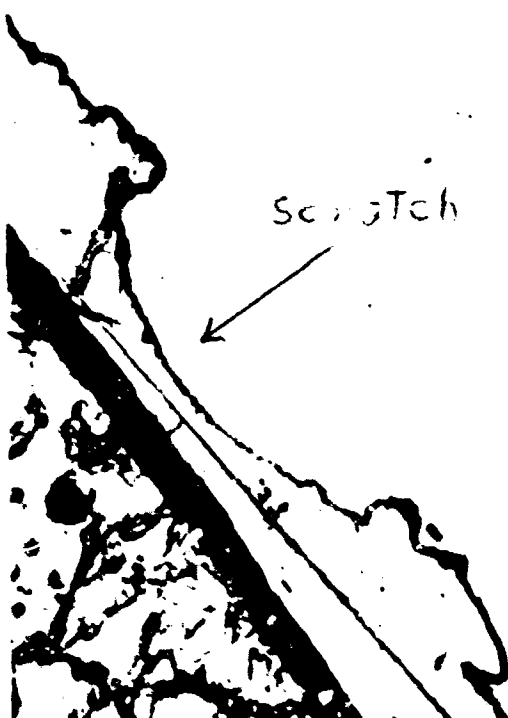
PHOTOMICROGRAPHS OF INDUSTRIAL PLATING PROBLEMS



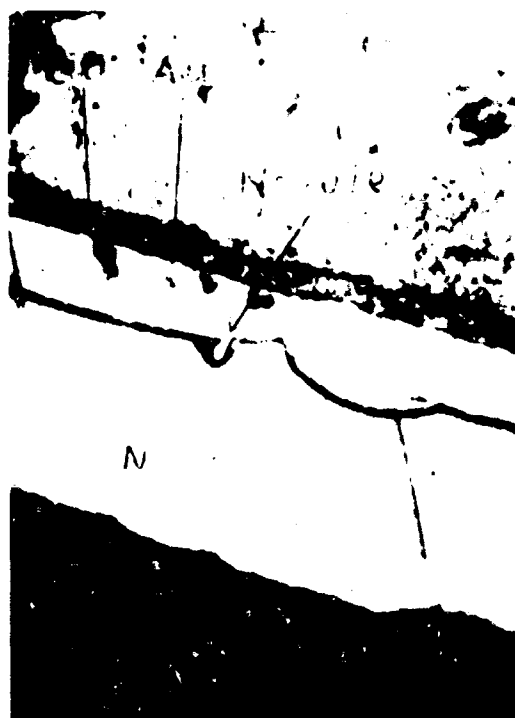
#1 Example of Poor Quality Assurance



#2 Typical Contact Machining Burr



#3 Contact Plating Scratch



#4 Plating Nodules

A. Photomicrographs Showing Plating Throwing Power into Deep Small Diameter Holes

1. Discussion

The purpose of this group of photomicrographs is to make a visual comparison and evaluation of the relative throwing and leveling power of various baths. All photomicrographs were taken at normal incidence to longitudinal section of a male contact (MIL-C-26636) mounted in bakelite. The positions photographed are illustrated below:

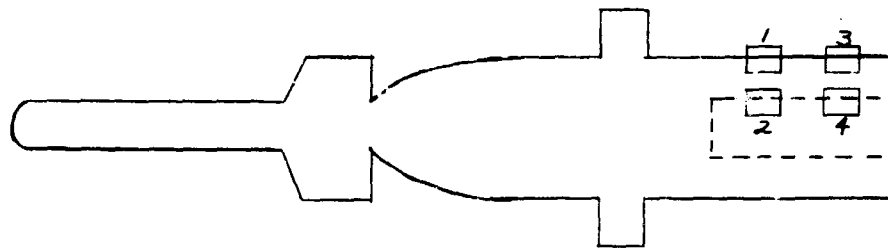


Figure 7

NOTE: The numbers in this illustration correlate with the photomicrograph location.

All photomicrographs were taken at a magnification of 750 power. Each subdivision of the superimposed scale subtends approximately 0.00010" of the subject plating. The functional plating on each photomicrograph is outlined by obvious markings. It should be noted that the various layers seen in most of the photomicrographs include the strike or activation plate on the basis metal and again on the plated layer being examined. The strike or copper plate applied to the subject plating is for activation for which follows a nickel plate. The final nickel plating is to give clarity to the microsection and to obtain a clear fine line at the edge of the plated layer for thickness readings, etc. The nickel will also minimize smearing effects when polishing a microsection of a soft plated layer like gold. This then can mean that in a particular photomicrograph one can have four to six plated layers shown. In each photomicrograph shown herein the subject plating will be clearly marked.

## 2. Observations

Note that in most cases, except for nickel plating, that at a position 0.150" to 0.169" inside the solder pot hole there occurred a substantial amount of plating. Compare the following thickness readings at the various positions taken. Position can be determined by the identification number and referencing Figure 7, page 230. Hole depth is 0.250".

	Ident.		Ident.	
	Nmbr	- Thickness TO	Nmbr	- Thickness
Rhodium/Base	A-1	0.00004"	B-2	0.00003"
All Parameters Std.	C-3	0.00006"	D-4	0.00004"
Tin-Nickel/Base	E-5	0.00070"	F-6	0.00020"
All Parameters Std.	G-7	0.00130"	H-8	0.00050"
10 ASF (Current Density)				
Tin-Nickel/Base	I-9	0.00070"	J-10	0.00026"
All Parameters Std.	K-11	0.00088"	L-12	0.00035"
3 ASF (Current Density)				
Orosene 999 Gold/ Nickel/Base	M-13	0.00011"	N-14	0.00009"
All Parameters Std.	O-15	0.00015"	P-16	0.00008"
Silver/Base	Q-17	0.00025"	R-18	0.00010"
All Parameters Std.	S-19	0.00025"	T-20	0.00017"

The throwing power of many of the baths tested herein may be evaluated from the photomicrographs included on the following pages. However, this evaluation is good only for piece parts of similar size and dimensions to the MIL-C-26636 contacts plated here. This is particularly true as a function of the hole diameter. The throwing power characteristics would change drastically if the hole diameter exceeded 0.750" or was below a diameter of 0.030".

It has been our experience and this contract work has beared it out for the most part, that when plating holes of diameters between 0.750" and 0.030" a plater can expect up to 50% thickness of plate on the inside wall, at a depth of two diameters. When investigating beyond the depth of two diameters the thickness usually falls off sharply. This rule is only a general rule of thumb.

Various metals and types of baths plate at different speeds and depths. For example, golds have better throwing power than tin-nickel or just nickel. However, silver has slightly better throwing power than golds in general and cyanide type gold baths have better throwing power than do acid type gold baths.

There are two other points that should be pointed out here and that is that cyanide gold baths are becoming less common and that throwing power or ability to obtain coverage on the inside dimension of a hole is often directly effected by the ability or quality of the strike plate preceding the actual functional plating. This is particularly true in cyanide gold, silver, and nickel plating.

As mentioned, acid golds are rapidly replacing cyanide type gold baths. This is because acid golds have better rinsing properties, they usually do not require a gold strike, and they have a smoother, brighter finish. It should also be pointed out, however, that acid golds are not as efficient nor do they have the throwing power that cyanide golds do.

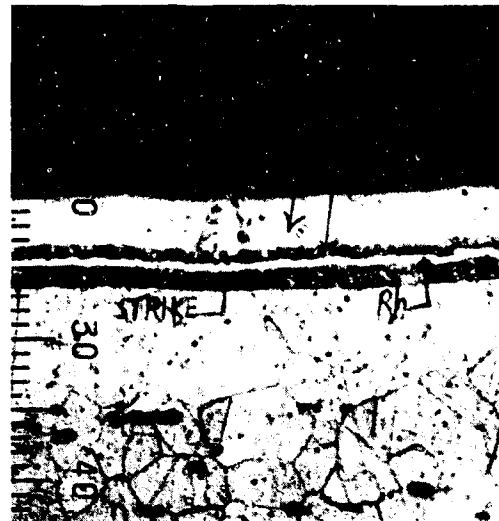
PHOTOMICROGRAPHS OF RHODIUM PLATING OVER BASIS METAL  
(Plating is 0.000051" Thick -- All Parameters Standard)

Photomicrographs A and B were taken 0.169" from crimp end of contact.

Photomicrographs C and D were taken 0.035" from crimp end of contact.



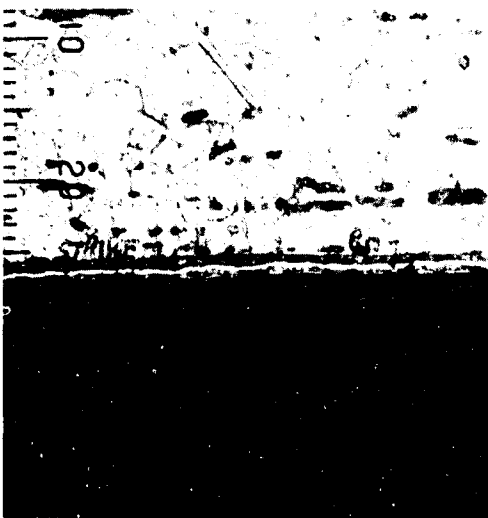
(A-1) Outside Barrel Wall



(C-3) Outside Barrel Wall

All Photomicrographs at 750 X

Each subdivision of the superimposed scale subtends approximately 0.000100" of the subject.



(B-2) Inside Barrel Wall



(D-4) Inside Barrel Wall

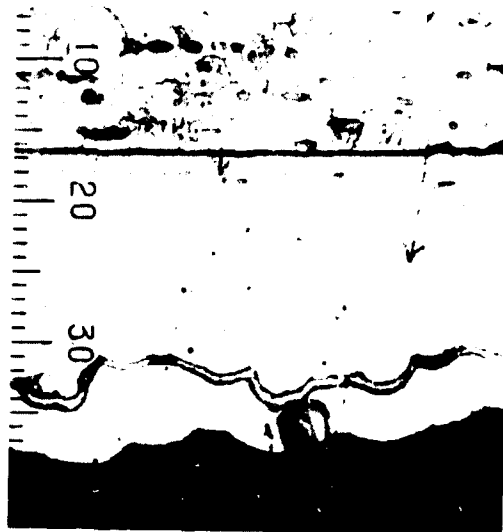
PHOTOMICROGRAPHS OF TIN-NICKEL PLATING OVER BASIS METAL  
(Plating is 0.000500" Thick -- All Parameters Standard)

Photomicrographs E and F were taken 0.161" from crimp end of contact.

Photomicrographs G and H were taken 0.031" from crimp end of contact.



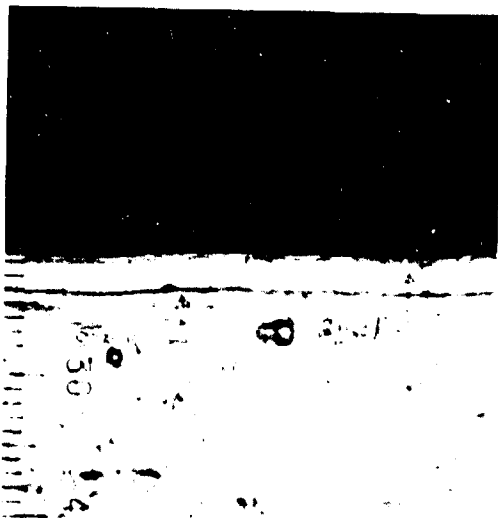
(E-1) Outside Barrel Wall



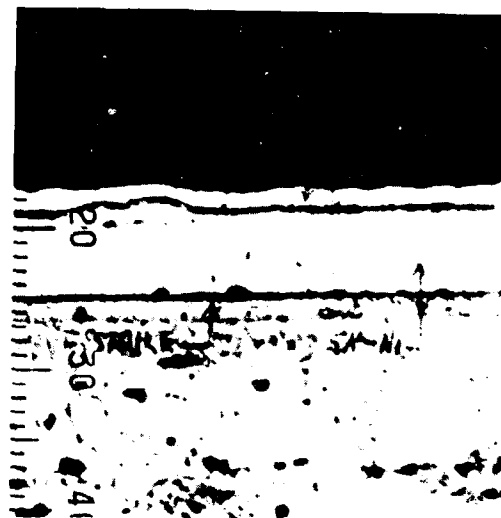
(G-3) Outside Barrel Wall

All Photomicrographs at 750X

Each subdivision of the superimposed scale subtends approximately 0.000100" of the subject.



(F-2) Inside Barrel Wall

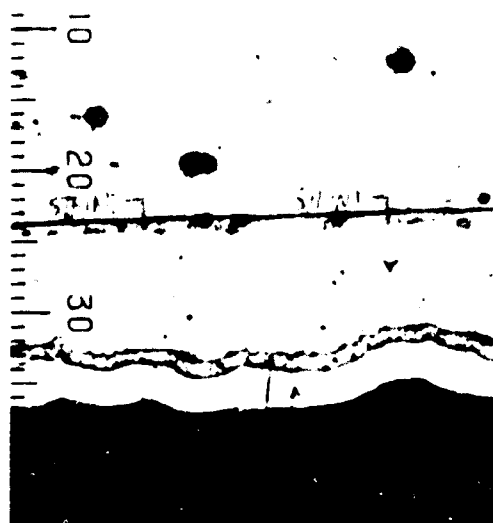


(H-4) Inside Barrel Wall

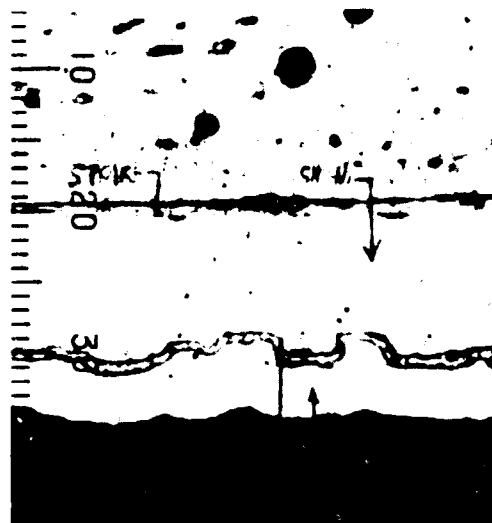
PHOTOMICROGRAPHS OF TIN-NICKEL PLATING OVER BASIS METAL  
(Plating is 0.000600" Thick -- Plated at Low Current Density,  
(All Other Parameters at Standard Level)

Photomicrographs I and J were taken 0.150" from crimp end of contact.

Photomicrographs K and L were taken 0.051" from crimp end of contact.



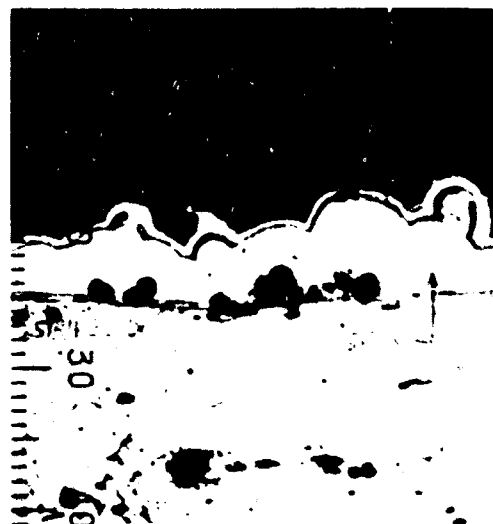
(I-1) Outside Barrel Wall



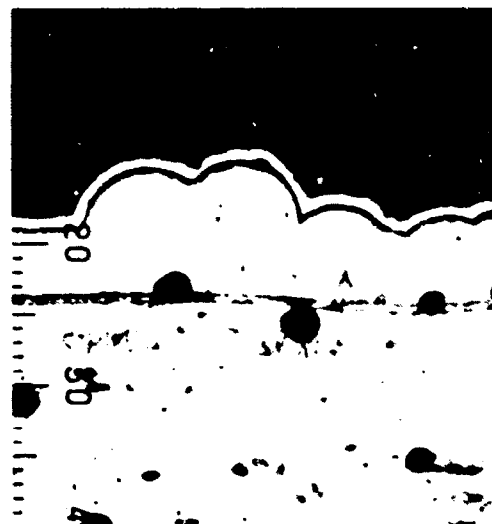
(K-3) Outside Barrel Wall

All Photomicrographs at 750X

Each subdivision of the superimposed scale subtends approximately 0.000100" of the subject.



(J-2) Inside Barrel Wall



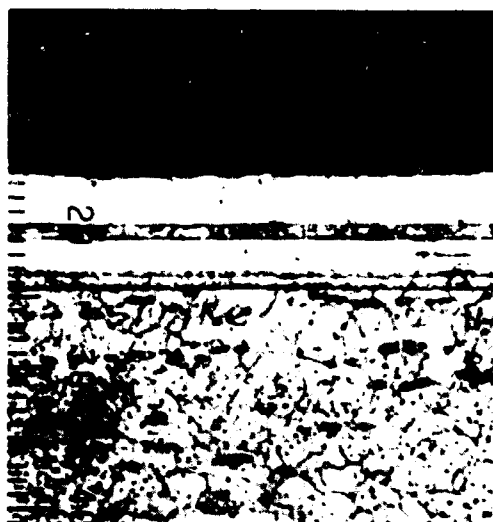
(L-4) Inside Barrel Wall



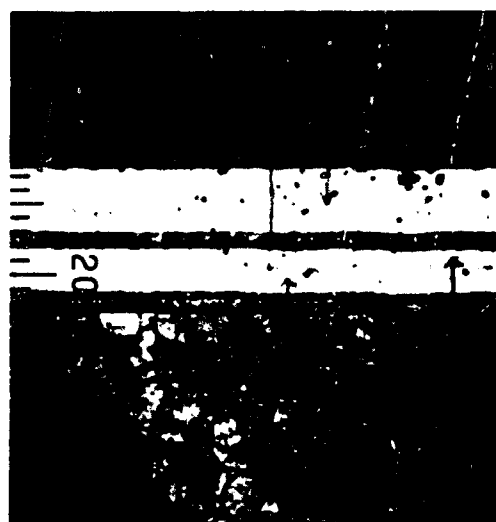
PHOTOMICROGRAPHS OF OROSENE 999 GOLD OVER NICKEL PLATING  
(Gold is 0.000168" and Nickel is 0.000190" Thick --  
Plated Using Standard Parameter Levels)

Photomicrographs M and N were taken 0.152" from crimp end of contact.

Photomicrograph O was taken 0.051" from crimp end of contact and Photomicrograph P is located 0.031" in from the end.



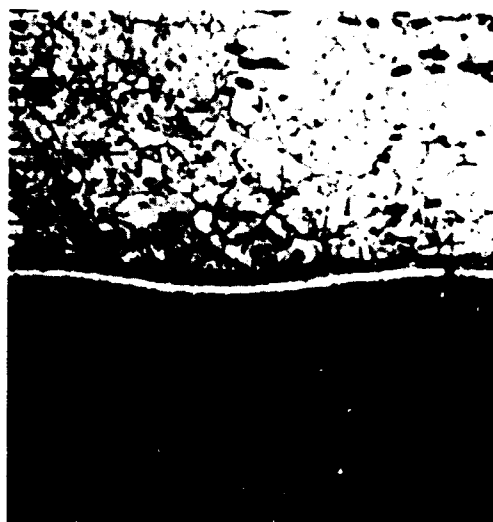
(M-1) Outside Barrel Wall



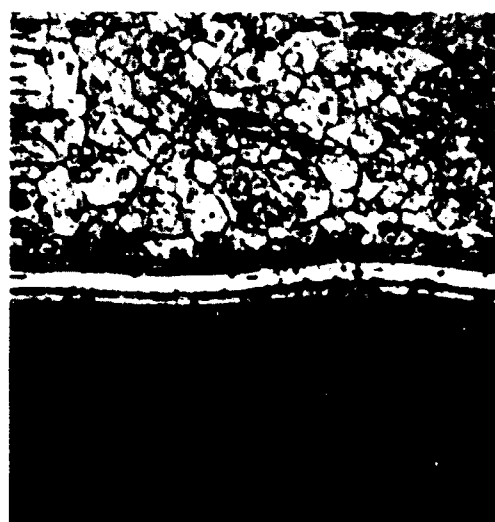
(O-3) Outside Barrel Wall

All Photomicrographs at 750X

Each subdivision of the superimposed scale subtends approximately 0.000100" of the subject.



(N-2) Inside Barrel Wall

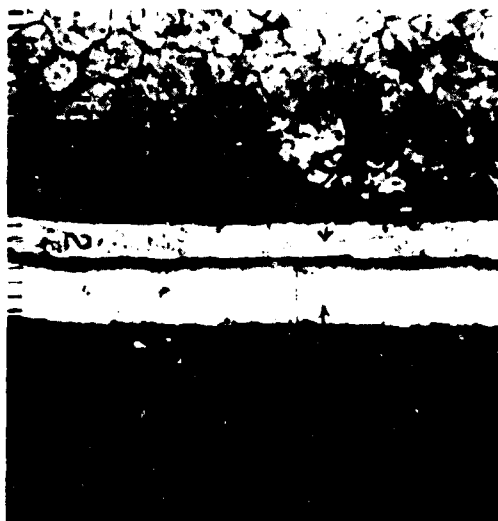


(P-4) Inside Barrel Wall

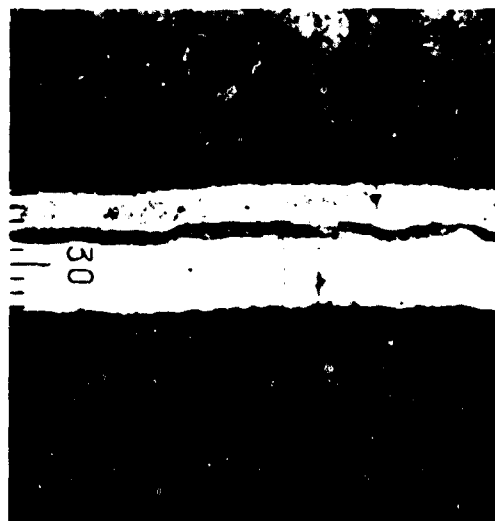
PHOTOMICROGRAPHS OF SILVER PLATING OVER BASIS METAL  
(Plating is 0.000261" Thick -- All Parameters Standard)

Photomicrographs Q and R were taken 0.161" from crimp end of contact.

Photomicrographs S and T were taken 0.043" from crimp end of contact.



(Q-1) Outside Barrel Wall



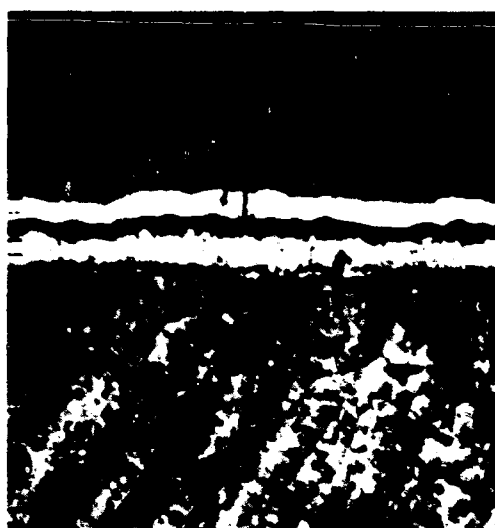
(S-3) Outside Barrel Wall

All Photomicrographs at 750X

Each subdivision of the superimposed scale subtends approximately 0.000100" of the subject.



(R-2) Inside Barrel Wall



(T-4) Inside Barrel Wall

XXIV.

SURVEY ON CONTACT AND PLATING SPECIFICATION INFORMATION

Discussion: A requirement of this contract was that on the basis of work performed herein, this contractor would recommend added information for military specifications covering aspects of this work that are not currently defined or adequately covered by existing military specifications. The approach taken to accomplish this was two-fold. First, we devised a survey letter which would be easy to answer and would request pertinent information on military specifications covering connector contacts and the plating thereof. This letter was sent to 350 connector users and manufacturers. From this we received thirty-six replies of which twenty-two had pertinent information.

The second approach was to study and evaluate current plating specifications with the purpose in mind of upgrading or rewriting these specifications. The results of this effort are concluded in the section of this effort entitled "Initial Draft for Military Plating Specifications."

It was intended that the referenced survey would contact users and manufacturers of connector contacts and thus give us a wide exposure to current specification weaknesses expressed by strong-minded people. This, therefore, would cover all types of contacts, quality levels, and applications. As evident, the response was poor; however, the results are reported here as a further guide to specification writing for plating and also for information purposes. All answers are shown here exactly as they were received.

A. Participating Companies of Survey Letter Analysis

Airborn Connectors Division; Dallas, Texas

AMP Incorporated; Harrisburg, Pennsylvania

Amphenol Corporation; Danbury, Connecticut

Applied Engineering Products Co.; Stamford, Connecticut

Questionnaire Returned Unidentified

\*The Bendix Corporation; Scintilla Division; Sidney, New York

Questionnaire Returned Unidentified

Questionnaire Returned Unidentified

Coastal Dynamics Corporation; Venice, California

Hollingsworth Solderless Terminal Co.; Ft. Lauderdale, Florida

Joy Manufacturing Company; New Philadelphia, Ohio

Questionnaire Returned Unidentified

Mandex Manufacturing Co., Inc.; Chicago, Illinois

Modular Electronics, Inc.; Osseo, Minnesota

North American Aviation, Inc.; Los Angeles, California

Questionnaire Returned Unidentified

Physical Sciences Corporation; Arcadia, California

Robertson Instrument Company; Azusa, California

Trompeter Electronics, Inc.; Canoga Park, California

Questionnaire Returned Unidentified

Winder Aircraft Corporation; Dunnellon, Florida

\* Two Replys

## B. Survey Questionnaire and Answers

What Type of Connector Do you Basically Manufacture?

1. Coaxial connectors of the type N, C, UHF, HN, BNC, TNC, all UG types and related specials.
2. High reliability, hermetic seal, high and low temperature, nuclear.
3. None
4. None. We purchase connectors.
5. Special - made to our specifications depending on project.
6. Multi contact cylindrical and rack and panel connectors.
7. Rack and panel - multi-pin.
8. Low cost terminal strips.
9. Manufacture solderless terminals.
10. Single pin jack coaxial.
11. Custom designed.
12. Coaxial.
13. R.F. Coaxial.
14. Do not manufacture connectors.
15. R.F. Connectors.
16. Component sockets; interconnection devices; integrated circuit mounts.
17. Printed circuit card connector rack and panel.
18. Coaxial.
19. About 90-95% are integrally molded to cable using polychloroprene, Funas, Bunan, Hypalon, Silicone.
20. A.N. Miniature, rack and panel, in accordance with MIL-C-5015, MIL-C-26482, MIL-C-21617, etc.
21. Printed Circuit.
22. Miniature, sub-miniature, micro-miniature, coaxial R.F. connectors.

If you procure connectors, to what specification do you normally purchase?

1. N/A
2. -
3. MIL-C-5015, MIL-C-26482, MIL-C-26500, and NAA specifications.
4. According to military specifications called for in bid set.
5. Depends on end use.
6. N/A
7. N/A
8. Commercial.
9. Manufacture them to MIL-T-7928.

10. -
11. Do not buy.
12. Military specifications for industrial and military equipment.
13. N/A
14. Military specifications where applicable MTL-C-26482, 21097, 8384, 21617. Internal drawings for other connectors.
15. -
16. Commercial.
17. For users to answer.
18. -
19. MS specifications.
20. Normally do not purchase connectors.
21. N/A
22. Do not purchase connectors.

From the connectors you purchase or distribute, what are the most common uses?

1. BNC.
2. Physical Sciences Corporation "TI" series.
3. Air vehicle interconnections.
4. -
5. Cables, probes and PCB's.
6. Aircraft, shipboard, missile, ordnance vehicles, ground support equipment.
7. -
8. TV and radio.
9. Ring and spade tongue.
10. Edge-lighted aircraft instrument panels.
11. Electroluminescent read-outs.
12. Our own are used for TV distribution systems, purchased units used for instrumentation.
13. N/A
14. Military specifications 26482, 21097, 8384, 21617.
15. Military application.
16. Test equipment.
17. For users to answer.
18. Patching.
19. Power transmission to 1000A industrial, military, etc., control underwater, airport lighting, automotive, steel, etc.
20. Air Force, space applications, ordnance.
21. N/A
22. -

In the specifications most often applied to your product, what suggestions could you make in the best interest of both the connector industry and the Air Force. Consider quality assurance, diversified specification coverage, consolidated specification coverage, and other parameters associated with value engineering and reliability.

1. Use of MIL-C-23329-A and MIL-C-39012 as the basic procurement specification.
2. General MIL Specifications do not cover our connectors. Connectors should be procured for the requirements, as in many cases the MIL specifications do not fulfill the needs.
3.
  1. Improve the major failure mode (bent pins) by recessing the pins in hard plastic.
  2. Prohibit use of silver plating or underplating.
  3. Require an effective, clearly defined manufacturer's quality assurance program (particularly final acceptance tests).
4. Fewer types - more standardization.
5. No comment.
6. We feel that specification writers would be in a position to provide better specifications if they had a greater familiarity with the connector industry. The study of material controls, manufacturing methods, manufacturing problems, component and finished assembly stocking procedures would be of much assistance in their work.
7. More consolidation of specifications with emphasis on performance rather than definite materials and processes. Then the MS could be more definitive because the user will see compatibility of materials, etc.
8. None
9. Have the specification state usage, reliability required and method of determining reliability based on this usage.
10. -
11. -
12. -
13. Standardization of finish and thickness between all branches of the service.
14. N/A
15. Eliminate duplication of specification on same or equivalent items, increase emphasis on performance, establish reliability criteria which can be applied to connectors which are passive elements and completely different from active elements such as electron tubes.

16. More detailed functional specifications.
17. For users to answer.
18. Suggest that government buyers consider quality along with price and not just buy based upon the lowest bidder only.
19. They should be more in the direction of performance specifications, while recognizing that dimensions must be set so far as necessary to insure interchangeability.
20. Suggest that controls established be based on performance rather than technique, with such limitations as thickness of plate which would be common to all similar units manufactured by various suppliers.
21. Consolidate specifications authority so that all quality assurance personnel can be working toward the same goal. Customers specifying requirements should identify definite specifications covering their requirements.
22. In MIL-G-45204 in 4.5.1, replace microscopic measurement with Beta-Ray Backscatter. In reference MIL-C-22557, improvement in female connectors negate requirements for beryllium copper as spring material should be less restrictive.

What appreciable difference do you note in Air Force, Navy, NASA, and commercial specifications?

1. Services seem to use the old military specifications uniformly. Commercial specifications are more detailed depending upon the specific application and/or the purchasing engineer's personal idiosyncrasies. NASA specifications are always more concentrated in the area of reliability and environmental performance.
2. None.
3.
  1. Military: lack of mating interchangeability; specification performance below part capabilities; lack of coordination between services.
  2. Commercial: better quality parts; performance requirements nearer to part capabilities.
4. Not enough to necessitate so many different numbers.
5. -
6. The differences in specifications of the various Services listed are merely in basic details.
7. Primarily in plating requirements - usually thickness.
8. No experience in military.
9. Government specifications are more complete. Interservice specifications are the same.
10. Test requirements.
11. -



12. None.
13. Wide variance in type and thickness of plating.
14. Incoming inspection, screening, preconditioning.
15. NASA specifications are overburdened with administrative quality control requirements which are impractical to apply to the small quantity NASA procurement.
16. Not fully advised on all these specifications.
17. Impossible to answer as a general question -- too involved.
18. None.
19. Commercial specifications are simpler while generally insuring the same degree of reliability in the necessary areas.
20. No major differences noted.
21. Different materials and finishes (not applicable in all cases). Different finishes most predominant.
22. -

What type of packaging for shipment is involved with your connectors?

1. Commercial-polycel bags. Military - MIL-STD-726A, Method IA-8.
2. .003 inch thick plastic bags.
3. Sealed in individual transparent bags.
4. Commercial.
5. Plastic sealed bags, depending on requirements.
6. Various packaging methods are employed from simplified to standard commercial practice to military specification requirements.
7. Individual pack - sulphur free paper.
8. Bulk.
9. Level A or B per MIL-P-116 and standard commercial.
10. MIL-STD-130.
11. As specified by customer.
12. Commercial.
13. Heat-sealed poly bag.
14. Individually in heat-sealed bags.
15. Unit pack is normally sealed polyethylene bag unless otherwise required in contract for export or other special end use. Outside package is commercial type of carton.
16. Poly bags and eggcrate boxing.
17. What customers specify.
18. Commercial.
19. All types.

20. Packaged as per applicable military specification and also to individual customer requirements.
21. Packaged designed to protect the item from damage during shipping, handling, and subsequent indoor storage for ninety days.
22. Heat sealed polyethylene bags.

What types, combinations, thicknesses of plating and military specifications are required on your connectors and connector contacts?

1. Silver (.0002 Min), gold (.00005 Min), cadmium, rhodium, albaloy, nickel and tin (.0002 Min). All copper flashed initially (to .001 when required).
2. MIL-G-45204, Type I, Class II, QQ-S-365a.
3. Follow connector MIL specifications except prohibit use of silver.
4. Every conceivable type.
5. Gold, silver, platinum, depending on end usage.
6. Silver over copper, soft gold over silver and hard gold over silver and copper in varying thicknesses from 50 millionths to 200 millionths. Also electrodeposited tin.
7. All MIL-G-45204 various thicknesses.
8. Cadmium plate.
9. Mostly tin per MIL-T-10727, Type I, thickness is .0003 to .0005.
10. QQ-P-416 - Class and type and gold and silver.
11. Tin, nickel, gold.
12. -
13. Normally .0002 min. silver on metal parts with .00005 min. gold flash on contacts.
14. .00005 gold over .0002 silver.
15. Most common finish is .0002 minimum silver plating. We add a gold flash of .00005 to center contacts as our standard practice.
16. Gold/nickel. Use ranges: .0005 to .00005 nickel, .00001 to .00007 gold.
17. No fast rule. There is no standard across the industry. Each customer specifies what he feels he needs.
18. Gold over nickel.
19. Silver - QQ-S-365, Type III .0002/.0004; Gold MIL-G-45204, Type II, Class 3 .0002/.0004 over .00005 copper; Cadmium plate - commercial grade.

20. Most of the elements generally electroplated are used on connector shells; the type of plating used would depend on the environment to which connectors are submitted. QQ-P-416, MIL-G-45204, QQ-S-365, etc.
21. MIL-M-19833A, MIL-M-14F, QQ-P-330, QQ-C-533, QQ-S-365a, MIL-G-45204, QQ-N-290, QQ-P-35.
22. MIL-G-45204, Class 5 on contacts, Class 4 on bodies.

Do your connectors have to withstand high temperature, \_\_\_\_\_ high insertion and withdrawal endurance, \_\_\_\_\_ or extreme vibration? \_\_\_\_\_. Please explain.

1. Only for some special requirements have we designed, fabricated, and tested high temperature, vibration and high mating insertion connectors.
2. Yes. Yes. Yes.
3. Yes. Yes. No. 250°F (total temperature) capability is a must for MIL-C-5015 connectors. NAS 1599/MIL-C-26500 392°F temperature is needed; 650°F (Total temperature) capability also needed. 500/1000 cycles of endurance required (higher for MIL-C-26518 type connectors).
4. Yes. Yes. Yes.
5. High insertion and withdrawal endurance. This also depends on end use; some items must withstand vibration, some plug in only once, others, many times.
6. We have special design connectors which are specifically intended for high temperature, high insertion and withdrawal endurance and extreme vibration. These are supplied for various projects as the applications dictate.
7. No. No. No.
8. Yes. No. No.
9. No. No. No. Vibration is only 10 to 55 cps, .016 inch total amplitude. Maximum temperature is about 120°C.
10. No. No. -.
11. Yes. -. Yes.
12. System connectors under vibration due to being pole mounted.
13. Yes. Yes. Yes. Particularly apollo requirements.
14. Yes. Yes. Yes. Required to meet all types of military environments 4158, 5272, 16400, 8189, 5400.
15. Standard military types - no. Special purpose custom made types - yes.
16. Yes. Yes. -. Environmental cycling and repeated use are very important criteria of our line.
17. Seldom. Yes. Seldom.
18. None.

19. Yes. Yes. Yes. Wide variation in industrial and military applications require design extremes in all categories.
20. Yes. Up to 400°F for extended time, 1000 cycles, 30 g up to 2000 cps.
21. Yes. No. No. 1. Our hermetic seals withstand high temperatures. 2. In most cases connectors never have to withstand more than 100 cycles.
22. Preponderance of applications for missiles, vehicular and test equipment. Temperatures to +150° 1000 insertions and withdrawals, 30 g's or 1/2" amplitude 5 to 2000 cps.

What are your most common problems in the manufacturing of connectors and contacts?

1. Government controlled MS drawings contain too many variations of connector components that could be standardized without penalizing performance.
2. Lead time -- too short delivery requirements.
3. Establishing and maintaining the necessary personnel knowledge and skills necessary for high performance.
4. -
5. Labor, machining contacts for good contact surfaces.
6. -
7. Not many, but principle ones are cadmium plating of hardware and gold plating of contacts.
8. Not enough lead time.
9. To obtain lots that are identical with each other.
10. Insulation materials.
11. Tolerance and good plating.
12. None.
13. N/A
14. N/A to us.
15. Control of dimensions on plated parts where tolerances are of the same order of magnitude as the required plating thickness.
16. Long life contact reliability - 10,000 insertions/withdrawals plating uniformity.
17. Too general a question to be answered specifically.
18. Being copied by unscrupulous companies, some of them quite big in size.
19. Soldering.
20. Staying within plating thickness requirement. The trend is to overplate to be certain to obtain the minimum thickness.

21. Short delivery schedules, specifications callout for exceeding intended use of connector.
22. Tolerances and finishes.

What are your most common problems with reliability in connectors and contacts?

1. A uniform standard of reliability does not exist. Improper attachment to cable more often degrades reliability than all other reasons combined. From the environmental standpoint, high potential breakdown at altitude and air or water leakage under pressures are the most significant design problems.
2. Hermetic seal.
3. Bent pins are most common (by far). Misapplications (designs) or incorrect assembly account for most of other problems. However, occasionally major "specification" problems arise, such as occurred due to the lack of 250°F performance requirements in MIL-C-5015.
4. Government inspection.
5. Poor metal to metal contact, spreading and loose fitting contacts.
6. Misapplication of connectors is the greatest problem in regards to reliability. Very often a design engineer will put a connector into an environment for which it was not designed with resultant failures and problems and an improper blame of the connector results.
7. No significant items.
8. None.
9. Proper usage and proper crimping methods.
10. None.
11. -
12. Moisture, oxidation, salt.
13. Meeting life test requirements.
14. Poor quality control.
15. Misuse and abuse by the user.
16. With purchased connectors frequent problems with failure (mechanical) after limited usage.
17. Low volume needs and high cost of qualification.
18. Misuse by personnel using the connectors. Also the original specifying of a connector not fitted to do the job.
19. Cable failure since our connectors are integral with cable in 90-95% of all designs.
20. Not a major issue in our plant. Reliability requires strict control of processes.
21. -
22. We have occasionally met with cracks in raw brass rod we use. Generally visual inspection is all that is needed.

In considering quality assurance for the type of connector you manufacture, in which order of importance would you place the following?

A. Basis Material

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
1	4	5	1	1	2	3	0

B. Design

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
11	5	2	0	0	0	0	0

C. Plating

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
0	1	4	6	2	2	1	1

D. Size of Connector and Contacts

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
0	3	1	4	5	1	1	3

E. Operational Environment

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
7*	1	1	3	4	1	1	1

F. Standard to Which Connector was Built

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
0	3	3	1	2	4	3	0

\*One company surveyed believes "Operational Enviroment" the most important and all other factors of approximate equal importance.

G. Cost of Manufacturing

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
1	1	1	3	2	2	2	4

H. Process and Quality Controls

Order of Importance							
First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth.
1	1	3	1	3	2	2	3

How do you think your suggested order of the above applies to other types of connectors? If it does not apply, please state difference.

1. About the same.
2. -
3. The reply to 11, above, was general.
4. See above.
5. The same.
6. We believe that the importance listing as shown in question (11) would apply in most cases.
7. Same.
8. -
9. Do not know.
10. -
11. -
12. -
13. No idea.
14. N/A
15. Yes.
16. Likely quite similar.
17. Depends upon design.
18. The same order.
19. Not as indicated because most of our connectors are proprietary designs so that H assumes lower rating.
20. No change.
21. About the same.
22. Larger connectors can relax tolerances and finishes.

Does skin effect exist in non RF connectors of the size 12, 16, and 20? If so, to what extent does it effect the performance of the connector?

1. No.
2. -

3. No effect has been observed (up to 400 cps).
4. -
5. Not to date.
6. We do not consider skin effect of particular importance in the low frequency ranges in which most of our connectors are utilized.
7. Not apparent in application of our units.
8. -
9. Have no experience in this area.
10. -
11. No.
12. -
13. Yes - dependent on frequency.
14. No.
15. N/A
16. -
17. If it is feared, coaxial should be specified.
18. No.
19. No, in our experience.
20. No.
21. N/A
22. No influence in small connectors we manufacture.

Do you approve of the type of high reliability required in MIL-C-26500? If no, why?

1. Yes.
2. Generally, this is not a well written specification. It does not include many important factors.
3. Approve of MIL-C-26500 in this regard. However, believe question must mean "MIL-C-38300." For MIL-C-38300, I don't believe the reliability requirements are feasible from both cost and time standpoints. (It is understood these requirements are being waived).
4. -
5. If the end use requires it, yes. If not, any MIL requirement generally is more costly, and in lots of cases is not needed. I cannot see adding cost to any item for any good reason.
6. To the best of our knowledge, there is no high reliability requirement stated in MIL-C-26500.
7. Yes.
8. -
9. Yes.
10. -
11. -
12. -



13. Yes.
14. No. 26500 is not representative of items required by us. In our opinion it does not represent high reliability, only high temperature.
15. -
16. Yes
17. Only needed in limited areas as evidenced by very limited government callouts.
18. No. The customer will not pay for it. This includes the government buyers who buy low price only from small houses who do not have any quality control policy or test equipment to measure electrical parameters.
19. We do not manufacture to this specification.
20. High statistical reliability is costly and should be limited to applications where it is absolutely necessary.
21. This specification applied to cylindrical type connector which we do not manufacture.
22. We do not manufacture to this specification and have no knowledge of it.

What type of metals do you primarily use for your connector contacts?

1. Male-brass; Female - HT Be Cu.
2. Stainless steel and thermocouple materials.
3. Copper alloys (actually, do not specify details).
4. -
5. Copper and brass, also depends on requirements.
6. Contact materials used in our connectors are namely copper alloy with a steel alloy used in hermetic.
7. Brass, Be Cu, Ph BRZ.
8. -
9. Terminals are made of copper.
10. Half hard brass.
11. Phosphor bronze, leaded brass.
12. Silver.
13. Brass for male, heat treated beryllium copper for female.
14. N/A
15. Center contacts male, brass; female, beryllium copper. Outer contacts phosphor bronze or beryllium copper as required by specification.
16. Beryllium copper exclusively, (some Inconel X).
17. Depends upon connector use.
18. Beryllium Copper.
19. In order of usage: (1) brass (2) copper (3) nickel (4) stainless 303.

20. Copper and copper alloys.
21. Beryllium copper, phosphor bronze, brass.
22. Brass.

Do you think a connector specification should stipulate the basis metal to be used in a connector contact. If so, why.

1. No. It should be built to a performance specification.
2. No. It should only set forth the requirements (electrical).
3. Interchangeability of tools, contacts, etc., requires performance and use type controls. Specifying the contact basis metal is no different than specifying the shell basis metal which is standard practice. However, other than connector MIL-specification controls of basis metal, it is not NAA-LAD practice to specify the basis metal.
4. -
5. Depends on user requirements. Just because a manufacturer produces an end item is no reason to feel that no one else knows anything about that type item, even though they may not be connected with it. Lots of manufacturers are so close to the product, they try to cover up the bad parts rather than admit them and correct them.
6. The answer to this question is a little more difficult because there are good and sound reasons for both the pro and con answer. To stipulate the base material used in contact would have a tendency to limit the state-of-the-art. A performance type specification tends to cultivate development of new materials and processes. On the other hand an exact alloy and plating callout would in some cases be attractive inasmuch as it would eliminate performance comparisons on fairly unimportant items such as a difference of 3% and 4% in millivolt drop for conductivity.
7. See question 4 and answer. (#4 - More consolidation of specifications with emphasis on performance rather than definite materials and processes. Then the MS could be more definite because the user will see compatibility of materials, etc.).
8. -
9. Yes, because this has quite an effect on voltage drop and useable life, for instance.
10. No.
11. Yes.
12. -
13. Yes. To assure reliability through entire life.

14. Basically no. Yes, if performance requirements cannot adequately or inexpensively determine acceptability.
15. Contact quality can be controlled by specifying either the material and process or performance requirements to be met by the part. Both are not needed but one is essential.
16. Yes. Basis metal very critical to performance. For high reliability application Be Cu or Be Ni far superior in reliability, repeatability and life to other metals.
17. No. Performance requirement.
18. No. Each specific application may require separate consideration.
19. No. In all cases, specifications should clearly state all conditions of usage and performance required. It should be up to the vendor to meet these conditions.
20. No. The specific material should be the option of the manufacturer.
21. Yes. Since the connector is based on the type of contact used.
22. No. Improved design allow cheaper materials to be used.

Do you denote a trend toward microelectronics and in particular connectors? If so, what are the problems and advantages of this?

1. The trend is much slower in coaxial than with power connectors.
2. No.
3. The trend is toward microelectronics and smaller connectors for aircraft (for example: BUWEPS ILAAS program). This is dictated by space and weight requirements. Increased attention to all phases of higher connector integrity is essential (higher quality, better training, etc.).
4. -
5. -
6. A very definite trend toward microelectronics or miniaturization in connectors has been noted. Advantages, of course, are in savings of space and some of the disadvantages, of course, have to do with the difficulty in working with the extremely small components. Inter-connections in many ways in the extreme micro miniaturization will undoubtedly have to be effected by new and varied techniques. Much additional research remains to be done in this line.
7. Yes. Principle problem is space for termination connecting.
8. -

9. Yes. The problem is manufacturing terminals smaller and smaller and still hold a high quality level. The advantage is the small size of the terminals.
10. None.
11. Yes. Problems are increased cost of manufacture and standards.
12. -
13. Not in coaxial.
14. Yes. Close spacings, less weight.
15. Size and weight reduction in connectors increases the Q.C. problem and reduces the performance capabilities. There is also a cost disadvantage in the subminiature connector.
16. Yes. Tremendous need for smaller connector inter/connect devices to go along with our electronic devices. Much problem here in dielectric parts.
17. Yes, but limited.
18. Not involved.
19. No, not here.
20. Yes, great strides are being made in this direction for space applications. Effort in this direction requires new tooling and training of personnel to deal with smaller arts.
21. Yes. Problems - closer tolerances relative to size of part. Advantages - microelectronics allows higher density and less weight.
22. We supply micro-miniature coaxial connectors to such manufacturers since they are compatible in size.

In your opinion, are the specifications for the electroplating of connectors or connector contacts adequate? If not, explain.

1. No. This should be specified by some type of operating test - contact resistance after X number of mating cycles for instance.
2. Yes.
3. High quality is needed. However, it is not readily apparent either that this is due to specification deficiencies or that new or improved specifications are required.
4. -
5. -
6. In general, we believe the specifications for electroplating of connectors and contacts are adequate.

7. See question 4 and answer. (#4 - More consolidation of specifications with emphasis on performance rather than definitive materials and processes. Then the MS could be more definitive because the user will see compatibility of materials, etc.).
8. -
9. Yes.
10. No. No Q.C. levels to be held.
11. Not always.
12. -
13. Yes.
14. No - Porosity not reflected in specifications. No check on final quality.
15. No. A single finish system will not be adequate for all specifications.
16. Generally.
17. Plating is a manufacturing technique that has many variables and should be judged on performance rather than manufacturing control.
18. No. We feel that silver is not satisfactory in many applications.
19. Yes, in our experience.
20. Yes.
21. Yes.
22. Generally yes. We suggest that specific undercoating be avoided as preventive advances.

Do you think the plating thickness and combination should be specifically spelled out in a military connector specification? Please explain.

1. No. This should be specified by some type of operating test - contact resistance after X number of mating cycles, for instance.
2. No. Only the electrical requirements to be met.
3. No, except to prohibit the use of silver. However, the MIL-C-26500 or NAS 1599 requirements are considered okay (except that they do not prohibit silver).
4. -
5. No. Depending on end use of the item you could again be requiring something not needed.
6. The same reasoning applies here as shown in (16) above. (#16 - The answer to this question is a little more difficult because there are good and sound reasons for both the pro and con answer. To stipulate the basis material used in contact would have a tendency to limit the state-of-the-art. A performance type specification tends to cultivate development of new materials and processes. On

the other hand, an exact alloy and plating callout would in some cases be attractive inasmuch as it would eliminate performance comparisons on fairly unimportant items such as a difference of 3% and 4% in millivolt drop for conductivity.).

7. Not in specification but in MS sheet.
8. -
9. Yes, this insures getting just what is required everytime.
10. Yes.
11. Yes.
12. -
13. Although not necessary, it would assure a better and more uniform product in the industry. Combinations not permitted should be specified.
14. See 16. (#16 -- Basically, no. Yes, if performance requirements cannot adequately or inexpensively determine acceptability.).
15. Yes, in order to maintain some minimum standards. However, options should be permitted subject to performance requirements.
16. Yes, very important to standardize to maintain functional uniformity between manufacturers.
17. See 18. (#18 - Plating is a manufacturing technique that has many variables and should be judged on performance rather than manufacturing control.).
18. No. Price and application should determine quality.
19. No. See 16 above. (#16 - Yes - in our experience.).
20. Yes.
21. Yes. Especially if competitive pricing is to be obtained.
22. I agree that plating thickness is adequate for general use. Specifying type of undercoating should be avoided. Specific tough applications such as presence of H<sub>2</sub>S or similar environmental should be spelled out when applicable.

What type of incoming inspection do you have on your connectors?

1. N/A.
2. -
3. Extensive type tests followed by sampling test programs.
4. -
5. Depending upon the specifications of purchase.
6. Not applicable.
7. N/A.
8. -
9. We manufacture them to the requirements of MIL-T-7928.

10. 100% or MIL 105 AQL.
11. MIL Standard sampling.
12. -
13. N/A.
14. Plating porosity, completeness of cure of plastic mold materials.
15. All parts are inspected for each attribute with AQL's per applicable connector specification and sampling per MIL-STD-105.
16. Depends on type of connector.
17. This is for users to answer.
18. 1% sampling rate.
19. Routine dimensional plus manufacturer's certification.
20. Require certification as to conformance to applicable specifications and inspection for proper assembly alignment.
21. MIL-STD 105c applicable 100% on first article inspection.
22. We do not buy connectors.

For military equipment applications of connectors, what method(s) of joining the connectors to the balance of the electrical circuit would you suggest for maximum reliability on a production basis. Suggested choices include welding, soldering, wire-wrap, crimping, compression bonding, taper-pin insertion, etc.

1. Crimping. No excess heat to swell dielectric, consistent joint, speed of assembly, repeatable and improved mechanical and electrical characteristics.
2. Welding.
3. The "one" choice is crimping. However, each application must be evaluated for the over-all picture. For a given case, any one of the methods listed may be the best choice.
4. -
5. -
6. As a supplier of connectors we make available connectors which utilize practically all conventional termination methods. We have noted that various customers have wide and varied opinions and preferences. Our effort here has been to supply the best quality contact possible for each requirement.
7. Any one could be most suitable. Depends on environment, quantity, cost and space.
8. -
9. Since ours are crimped terminals, we do not have enough experience with the other types to make reliability comparisons.
10. Soldering with mechanical bond.

11. -
12. -
13. Soldering, screwing or crimping.
14. Depends on application - prefer wire-wrap for PC back-place.
15. Hex crimp to coaxial cable outer conductor. Hex crimp or solder to center conductor. This will give high strength, repeatability of connector performance, reduced need for field servicing.
16. Depends on application.
17. Crimp, TERMI-POINT, or Taper Technique.
18. Soldering, wire-wrap and soldering; do not favor crimping of center contact in coaxial connectors.
19. Crimping.
20. Soldering and crimping. Soldering requires intensive training. Crimping requires exact control of tooling and is less subject to human error.
21.
  1. Soldering - provided a mechanical joint is also made.
  2. Wire-wrap, taper, pin, crimping.
  3. Welding - depending on type of equipment used.
22.
  1. Welding.
  2. Soldering; - for R.F. use.

Do you have any suggestions relative to military connectors that should be reviewed in consideration of further development work?

1. Concentrate on completing 39012 and then continue to evaluate against it to polish it up after initial release.
2. Specifications should cover only basic mating and performance requirements.
3. Upgrade performance requirements to reflect "beat part" capabilities. Stiffer supplier Q.C. requirements.
4. -
5. No comment.
6. This Division would very much like to see intensive research work done to develop high temperature fuel resistance elastomers with a particular attention given to physical strength. Additional work could also be done in platings for contacts and finishes for other metal parts for high temperature environment.
7. See No. 4. (#4 - More consolidation of specifications with emphasis on performance rather than definite materials and processes. Then the MC could be more definitive because the user will see compatibility of materials, etc.).
8. -
9. Not at this time.



10. No.
11. -
12. -
13. N/A.
14. Do not permit present groups to continue development. They are biased, selfish, self-perpetuating, limited in outlook, unable to compromise and unresponsive to modern needs.
15. None.
16. No.
17. No general study will be fruitful.
18. Too many versions of coaxial connectors that are very poor.
19. No.
20. Incorporation of new classes for higher temperature performance in the area of 400°F.
21. The printed-circuit board or P.C. connectors should specify a +/- .004 or closer tolerance, including circuitry and plating.
22. Connectors for welding applications require different designs.

How do you classify the general level of military connector specifications today?

1. Any move in the direction of 39012 is an improvement.
2. Poor.
3. MIL specification connectors must be classed as "fair."
4. -
5. I wouldn't dare say.
6. In general the military specifications today are adequate up to a given point. Upgrading is currently needed in some cases and we know from Military agency contracts that this process is being effected.
7. See No. 4. (#4 - More consolidation of specifications with emphasis on performance rather than definite materials and processes. Then the MS could be more definitive because the user will see compatibility of materials, etc.).
8. -
9. Adequate for general use.
10. No. Do not spell out end use.
11. -
12. -
13. Good with MIL-C-39012.
14. Terrible, inadequate, a technical disgrace.
15. Fair.

16. Much improved recently.
17. Confusing; lack of cooperation between services.
18. Too detailed and limited. We do not abide by military specifications and make connectors as we deem necessary.
19. Varied.
20. Good.
21. Good.
22. In general, good.

Can you suggest any good, reliable and economical incoming quality assurance checks for connectors and contacts? Please list and describe tests.

1. High potential, swept VSWR, mating life, retention force, contacts resistance (after), environmental, mating face dimensional, cable pull-out.
2. We use 100% inspection.
3. No. I recommend increased connector manufacturer quality control; then seal the connectors and contacts until actual use. User's type tests and sampling tests should parallel the MIL specification requirements for qualification and requalifications.
4. -
5. No comment. Plain common sense on the part of those people performing the tests. People who understand the test, the requirements needed and WHY any type test by any type equipment is only as good as the people performing the test.
6. -
7. Sorry, no specific ones which are not already used.
8. -
9. No. This would depend on usage and desired reliability.
10. No 9858.
11. -
12. -
13. Contact life - both contact life and thickness tests on random basis.
14. This is proprietary information.
15. Functional gaging. Performance depends on assembling connector to cable and therefore, it is not readily checked at incoming inspection.
16. Dual contact c/r testing per cycle life on small lot basis and instantaneous c/r test (three tensile) 100%.
17. For users to answer.
18. Common sense applied to the applied use.
19. Connector applications are too varied to permit any general test covering all.

20. None. It is most economical to rely on certification; however, this has its drawbacks. Assurance of reliability of incoming material can be arrived at only through intensive in-house periodic requalification testing.
21. MIL-STD-2-2c. 1. Insertion and withdrawal test, - contact and assembly test. 2. Moisture resistance. 3. Dielectric withstanding voltage. 4. Insulation resistance (altitude), 5. Contact resistance. 6. Thermal shock test. 7. Vibration.
22. On sampling basis check, plating with Beta Ray equipment assembled connectors may be tested for dielectric volume resistance. Contacts may be checked for ohmic resistance.

XXV.

PROPOSED MILITARY SPECIFICATION

A. GOLD PLATING OF CONNECTOR CONTACTS, GENERAL SPECIFICATION FOR

1. SCOPE

1.1 This specification covers the electrodeposition of gold applied to pin and socket non R.F. electrical connector contacts of the high reliability type. The contacts to which the gold is to be applied shall be machined of one of the following: leaded copper; nickel silver; nickel iron; phosphor bronze; chrome copper; beryllium copper; leaded brass; or tellurium copper. The purpose of this specification is to assure the highest standards of quality for gold electrodeposits on electrical connector contacts in order that functional reliability needed for such contacts is maintained and assured.

1.2 Classification. Gold platings required to meet this specification shall be of the following types and classes:

1.2.1 Types

Type I	Pure Gold (soft plate)
Type II	Hard Gold Plating
A.	Minimum hardness of 200 diamond pyramid.
B.	Minimum hardness of 110 diamond pyramid.
Type III	High alloy (less than 95.0% gold content) Hard Gold Plating.

1.2.2 Classes. The eight classes of gold plating, established by minimum thickness requirements, are defined in Table I.

TABLE I. - CLASS DESIGNATIONS

Class	Minimum Thickness Inch	Class	Minimum Thickness Inch
1	*0.000050 Maximum	5	0.000200
2	0.000050	6	0.000300
3	0.000100	7	0.000500
4	0.000150	8	**Greater Than 0.000500

\*Shall be of sufficient thickness to exhibit a uniform color.

\*\*Shall be specified in the detailed specification.

## 2. APPLICABLE DOCUMENTS

2.1 The following standards, of the issue in effect on date of invitation for bids, form a part of this specification.

### STANDARDS

#### Federal

Fed. Test Method Std. No. 151-Metals; Test Methods

#### Military

MIL-STD-105-Sampling Procedures and Tables for Inspection by Attributes.

MIL-STD-109-Inspection Terms and Definitions.

Air Force Project Nr. 7-960 Final Report.

## 3. REQUIREMENTS

3.1 Plating materials and processes. The materials and processes used shall produce coatings that meet the requirements of this specification. Type I (pure deposit-soft in nature) plating shall be 99.8 per cent gold minimum. Type IIA plating shall be 99.0 per cent gold minimum. Type IIB plating shall be 95.0 per cent gold minimum. Type III shall include all gold platings having less than 95.0 per cent gold content. For Types II and III gold plating, a bright finish is preferred; however, matte deposits are acceptable when a bright finish has not been specified.

3.2 Basis Metal. The basis metal shall be free from all defects that will be detrimental to the utility, appearance, or protective value of the plating.

### 3.3 Process Requirements.

3.3.1 Preplating Operations. Unless otherwise specified in the detailed specification (see 6.1), gold plating shall be applied after all basis metal heat treatments and mechanical operations (such as machining, brazing, welding and forming) have been completed. If postplating operations are necessary, such operations shall be performed before acceptance tests.

3.3.2 Surface Cleaning and Activation. The surface shall be cleaned and activated by a process optional to the plater if it is not specified in the detailed specification. Care shall be taken in the use of bright dips or other etchants to prevent excessive metal loss where dimensional tolerances and surface characteristics must be maintained.

3.3.3 Strikes and Underplating. When a strike electro-deposited coating is necessary, it shall be applied immediately after activation when all basis metal surfaces are wet. When gold is to be applied to a nickel underplate, a suitable nickel strike shall be applied to the underplate prior to plating gold. When gold is to be applied to a copper alloy basis metal, a copper strike of no less than 0.000020 inch thick shall be applied to the basis metal. When the basis metal is nickel iron, a nickel strike such as "Woods Nickel" shall be applied to the basis metal before plating gold.

3.3.4 Plating. Activation shall immediately precede all plating operations. Unless specified in the detailed specifications, the plating process and plating solutions employed shall be optional provided that the selected process produces platings which meet the requirements of this specification.

3.3.5 Rinsing. After plating, residual plating salts shall be removed from plated articles.

#### 3.4 Properties of Plating:

3.4.1 Thickness. The gold thickness shall be measured in accordance with 4.4.2. The thickness requirement in Table I (See 1.2.2) shall be met for the class that is specified and shall apply to all functional and significant surfaces. Unless otherwise specified, metallic surfaces of the contacts to which the plating solution has access shall be covered with gold sufficient to exhibit a uniform gold color.

Functional Surfaces are those surfaces so defined by the detailed specification. These are areas that are usually subject to wear and corrosion.

Significant Surfaces are those surface areas that can be touched by a ball having a diameter of 0.75 inches unless they include the following interior surfaces. Interior surfaces such as holes, slots, keyways, or similar configurations beyond a distance within the configuration and equal to the smallest dimension of the entrance are not significant surfaces.

3.4.2 Appearance (see 4.4.1). The gold plating shall be free from nodules, blistering, tarnishing, peeling, flaking, pits, burned areas and discontinuities such as unplated areas, gouges, scratches, and cracks. Any other visible defects

which detrimentally affects the utility, protective value and wear resistance of the plated contact shall be cause for rejection. Rack marks shall not be acceptable unless specified on the detailed specification. The plating shall be uniformly smooth over all functional surfaces. (See 3.4.1). Basis metal defects which cause plating to be irregular and/or discontinuous shall be cause for rejection. (See 3.2).

3.4.3 Adhesion. The gold plating, including any electro-deposited underplating shall adhere to the basis metal and/or to the underplating and shall show no separations when tested in accordance with the Baking Test 4.4.3.1. The Bend Test 4.4.3.2 and the Cutting Test 4.4.3.3 shall be performed when specified in the detailed specification.

3.4.4 Hardness. All gold platings of Type II shall have a diamond pyramid hardness as specified in Table II when tested in accordance with 4.4.4.

TABLE II. - SUBTYPE HARDNESS

Subtype	Minimum Hardness-Diamond Pyramid
IIA	200
IIB	110

3.4.5 Porosity. The average quantity of copper dissolved per unit tested area shall be less than the maximum specified in Table III when tested in accordance with 4.4.5.

TABLE III.

The values for this table have not been established for commercial uses at this time.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Process Control. High quality electrodeposited coatings on connector contacts shall be maintained by adherence to superior processes as well as regular maintenance of solution compositions and calibrations of equipment and controls. Platers shall maintain complete records and practice these qualities of good workmanship.

4.2 Responsibility. Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements prior to the submission for government inspection

and acceptance. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. Inspection records of the examinations and tests shall be kept complete and available to the government as specified in the contract or order.

4.3 Sampling Plan. Inspection and testing required herein shall consist of lot-by-lot inspection.

4.3.1 Lot-by-lot Inspection. Connector contacts selected for lot-by-lot inspection shall be sampled in accordance with 4.3.3 for nondestructive tests and in accordance with 4.3.4 for destructive tests.

4.3.2 Lot. A lot shall consist of contacts conforming to the same part number, plated by the same processes with the same equipment and submitted for inspection at the same time.

4.3.2.1 Proof of Identical Production. When required by the procuring agency or the government inspector, the contractor shall furnish proof that all articles in a lot submitted for inspection were plated under as nearly identical conditions as possible. Such proof may include information on the racking of parts, composition of solutions, voltages, current densities, cycle time and temperatures during plating operations.

4.3.3 Sampling for Nondestructive Tests. Samples for nondestructive tests shall be selected in accordance with MIL-STD-105, inspection level III. Acceptable quality level (AQL) shall be 1.0 per cent defective. Other sampling procedures may be substituted when authorized by the procuring agency.

4.3.4 Sampling for Destructive Tests. Unless otherwise specified, the samples for destructive tests shall be composed of four plated contacts selected at random from each lot. The procuring agency may change the number of samples required or specify the use of sampling procedures contained in other publications.

4.4 Acceptance Tests.

4.4.1 Visual Inspection for Acceptance. Samples selected in accordance with 4.3.3 shall be visually examined for compliance with the requirements of 3.4.2. The samples shall be examined at a minimum of four-power magnification. If the number of defective samples exceeds the permissible acceptance



number for the size of lot under inspection, the lot represented by the samples shall be rejected.

4.4.2 Thickness of Plating. The plating thickness shall be measured by any suitable method capable of giving results which are within 5 per cent or 0.000005 inch of the true thickness. Unless otherwise specified, thickness readings shall be taken from each of six (6) plated contacts sampled at random from the lot. A minimum of three (3) thickness readings shall be taken from each of the sampled contacts. If a functional surface is specified, the readings shall be at random locations on the functional surfaces (see 3.4.1). If a functional surface is not specified, the thickness readings shall be at random locations on the significant surfaces (see 3.4.1). If any thickness reading taken from a functional surface is less than the specified minimum or greater than the specified maximum, the lot represented by the samples shall be rejected. (See Table I). When the functional surface is not specified, the lot shall be rejected if the average of the thickness readings taken from any contact is less than the specified minimum or greater than the specified maximum. (See Table I). The "Beta-Ray Backscatter" method is acceptable for measuring gold and silver thicknesses on external surfaces. This method is not applicable for measuring gold plating thickness when underplates of heavy metals such as rhodium and silver are present. Method 521 (microscopic method) of Fed. Test Method Std. No. 151 with the modification of Table IV shall be used in cases of dispute.

TABLE IV  
Modification in Procedure for Test Method 521  
(Fed. Test Method Std. No. 151)

Step In Test Method 521	Modification
Selection of Section for Test	Use a perpendicular cross section of the selected specimens.
Preparation of Specimens; Mount- ing Specimens.	Plate the articles with a coating at least 0.003 inch thick of copper, nickel or iron to protect the edges during grinding and polishing. The first layer of overplate should be a copper strike deposited from a cyanide solution, followed by the relatively thick overplate.
Preparation of Section.	Grind and polish as indicated, following the instructions for polishing zinc, cadmium, tin and lead coatings.
Etching.....	Use an etching solution consisting of one part nitric acid (specific gravity 1.42) to 19 parts alcohol (95 per cent).
Procedure; Use of Microscope.	Take a minimum of five measurements at random locations on the specimens. Measurements shall be expressed to five decimal places. The magnification should be at least 500 diameters.

#### 4.4.3 Adhesion of Plating.

4.4.3.1 Baking Test. Plated samples selected in accordance with 4.3.3 shall be heated for 1/2 hour at 375°F +/- 10°F. Evidence of flaking, peeling, cracking or blistering shall be cause for rejection of the test contacts. If more than 1.0 per cent of the sampled contacts have such defects, the lot represented by the sampled contacts shall be rejected. This test is nondestructive, and nondefective contacts tested by this method may be returned to the lot.

4.4.3.2 Bend Test. Plated samples for the bend test shall be selected in accordance with 4.3.4. The test samples shall

be repeatedly bent  $180^\circ$  in any direction around a diameter equal to the thickness of the specimen until the basis metal fractures. The plating adjacent to the fracture shall be probed with a sharp instrument in an attempt to detach such plating. Any plating detached from the basis metal in this manner shall be cause for rejection of the lot from which the contacts were sampled.

4.4.3.3 Cutting Test. Plated samples selected in accordance with 4.3.4 shall be cut away from the basis metal with a sharp edged tool and examined under four power magnification. Evidence for lack of adhesion shall be cause for rejection of the lot represented by the sampled contacts.

4.4.4 Hardness. The samples selected in accordance with 4.3.4 shall be tested by method 244 of Fed. Test Method Std. No. 151.

4.4.5 Porosity Test. The porosity test is a measure of the ability of the plating to shield the underlying basis metal from substances which could cause surface oxidation and corrosion. This test exposes the plating to a liquid solution which migrates through the pores of the plating and which is capable of dissolving the basis metal copper alloy. The quantity of copper dissolved during a timed test period determines the plating porosity. Ultrasonic agitation is applied during exposure to accelerate the test. Porosity is measured in surface deterioration - dissolved weight of copper per unit area per unit time (mg/sq inches/Std time unit). This test is applicable only to platings in which the basis metal is a copper based alloy. Figure 1 is a sketch of the test apparatus. The test specimen is suspended in a test tube containing a solution of ammonium persulphate and ammonium hydroxide. After a timed test period with ultrasonic agitation, the color density of the test solution is compared to a standard color density. A test solution of lighter appearance than the standard indicates an acceptable test result.

#### Materials and Equipment Required.

Ultrasonic tank and generator. The ultrasonic tank and generator shall have a frequency of  $40 \pm 3$  kilocycles per second. The signal may be modulated. The maximum pulse power input to the tank shall not be more than three times its average input power.

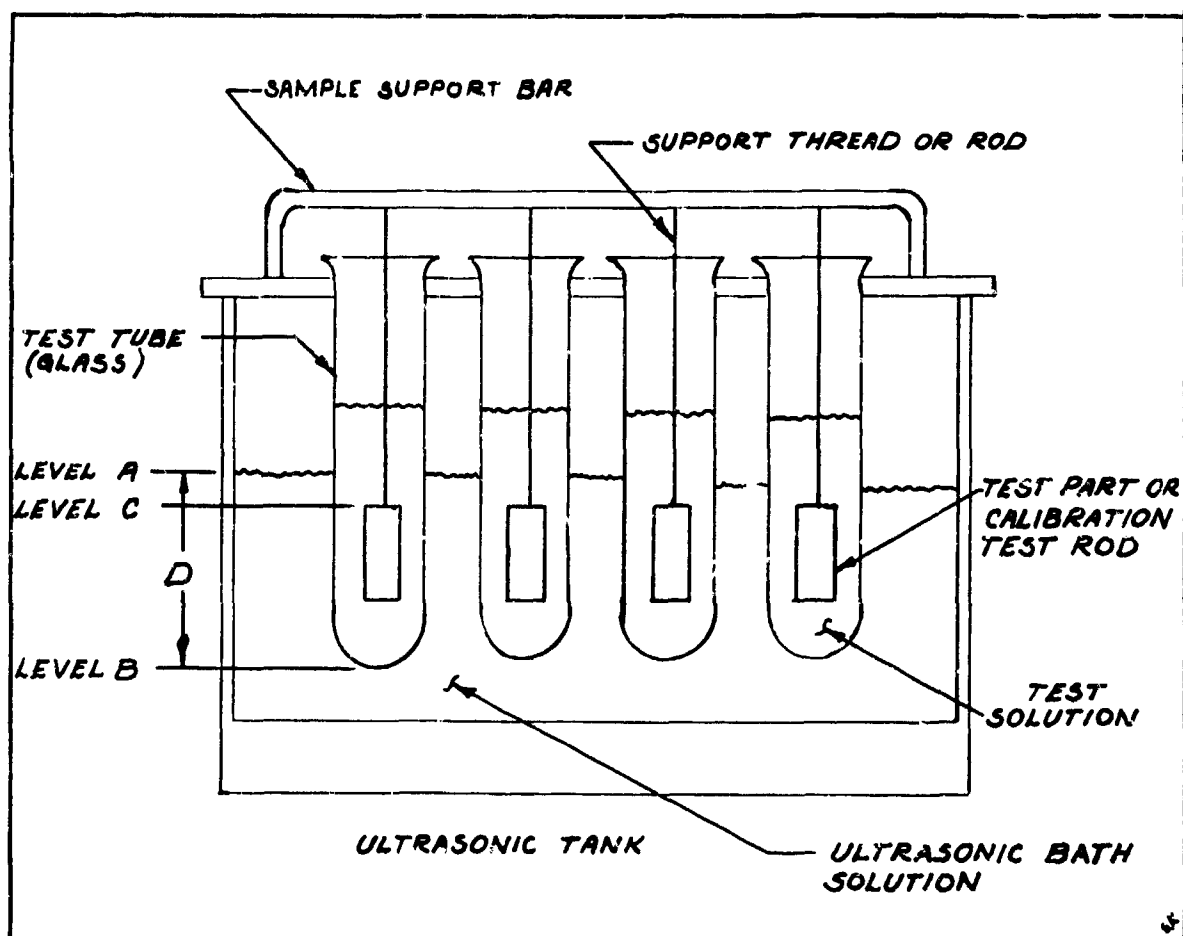


Fig. 1

**Test Solution.** The test solution shall consist of one unit volume of concentrated ammonium hydroxide (29 +/- 2%  $\text{NH}_4\text{OH}$  reagent grade) and one unit volume of 1.0 molar ammonium persulfate (aqueous solution of reagent grade  $(\text{NA}_4)_2\text{S}_2\text{O}_8$ ).

**Preparation:** (For approximately one liter) 114 grams of AR grade ammonium persulfate shall be dissolved in enough demineralized or distilled water to make a solution of 500 milliliters. 500 milliliters of concentrated AR grade ammonium hydroxide shall be added to this solution. This mixture shall be made completely homogeneous by agitation. This solution spontaneously decomposes and shall not be used for this test after thirty (30) hours from the time of preparation.

**CAUTION:** Preparation and handling of this solution should be done where fumes are rapidly removed. Contact of this solution with combustible material must be avoided.

Ultrasonic Bath Solution. The ultrasonic bath solution shall consist of an aqueous solution of some suitable substance (usually a soap or detergent) such that the ultrasonic unit is calibrated. (See calibration of ultrasonic unit).

Standard Reference Solutions and Containers. Each reference solution shall be 10.0 +/- 0.5 ml of an aqueous solution consisting of copper sulfate ( $\text{CuSO}_4$ ) and ammonium hydroxide ( $\text{NH}_4\text{OH}$  AR grade).

Preparation: 1.000 +/- 0.005 grams of 99.9 per cent pure copper wire shall be dissolved with 20 ml of concentrated  $\text{HNO}_3$ . This shall be diluted to 1.000 +/- 0.005 liters with demineralized or distilled water. The resulting solution contains 1.0 milligrams of copper per milliliter and is concentrate #1. 10.0 +/- 0.1 ml of concentrate #1 shall be diluted to 100.0 +/- 0.1 ml with demineralized or distilled water, and the resulting solution shall be concentrate #2.

The standard solutions included in Table V shall be prepared. The standard solution shall consist of mixing the specified volume of the specified concentrate indicated in Table V with 2 ml of concentrated ammonium hydroxide and sufficient distilled or demineralized water to make a solution of 10.0 +/- 0.5 milliliters.  $AXW_s$  shall be the copper content in milligrams in the requirement standard where (A) is the exposed plated area of the sample and ( $W_s$ ) is the minimum ( $\text{mg}/\text{in}^2$ ) required in Table III. (A) shall be within 5.0 per cent of the true exposed plated area.

**CAUTION:** The ammonium hydroxide content decreases during periods when the test tubes are uncovered; this loss shall be recovered by maintaining the solution level at the 10 +/- 0.5 ml level by the addition of concentrated ammonium hydroxide.

TABLE V  
Standard Reference Solutions

Volume of Concentrate	Concentrate	Copper Content of Standard
2.0 ml	#2	0.20 mg
4.0 ml	#2	0.40 mg
6.0 ml	#2	0.60 mg
8.0 ml	#2	0.80 mg
1.0 ml	#1	1.0 mg
1.5 ml	#1	1.5 mg
2.0 ml	#1	2.0 mg
2.5 ml	#1	2.5 mg
3.0 ml	#1	3.0 mg
3.5 ml	#1	3.5 mg
4.0 ml	#1	4.0 mg
5.0 ml	#1	5.0 mg
8.0 ml	#1	8.0 mg
(A)X(W <sub>S</sub> ) or (10)X(A)X(W <sub>S</sub> )	#1	(A)X(W <sub>S</sub> ) mg
	#2	(A)X(W <sub>S</sub> ) mg
		Requirement
		Standard

Each solution shall be contained in a completely transparent glass test tube with dimensions 20 mm diameter X 150 mm length. These test tubes containing the reference solutions should be stoppered when not in use.

Calibration of Ultrasonic Unit. Calibration of the ultrasonic unit shall be performed once during every three month period as a requirement of this unit for the porosity test. The calibration shall consist of the following steps (1 through 7) performed in the same order:

Step 1. Each of four (4) cylindrical leaded brass rods (approximately 1 inch X 0.1 inch diameter) shall be degreased, cleaned, dried and then weighed to within  $\pm 0.0002$  grams. The leaded brass rods shall have the composition: 59  $\pm$  3.0% copper, 39  $\pm$  3.8% zinc and 2  $\pm$  1.0% lead.

Step 2. The ultrasonic tank shall be filled with the ultrasonic bath solution to a fixed bath level previously selected for convenience and utility (usually 1/2 full). The depth of the solution shall be within 5.0 per cent of the depth corresponding to this fixed level for all calibration and porosity tests.

Step 3. Four (4) glass test tubes 20 mm X 150 mm in size shall be filled with  $10 \pm 0.5$  milliliters of the test solution. These test tubes shall be suspended vertically in the ultrasonic bath with distance D at  $1.5 \pm 0.2$  inches as shown in Figure 1. The temperature of the bath and the test solution within the test tubes shall be maintained at  $30 \pm 2^\circ\text{C}$  for all calibration and porosity tests.

Step 4. The ultrasonic unit shall be turned on and the generator shall be tuned to the maximum power output or to a power output which has previously been found to provide the correct calibration.

Step 5. Each previously cleaned and weighed leaded brass rod shall be completely submerged into one of the test solutions receiving the ultrasonic agitation. The supporting material shall be inert to the test solution. The position of the test rod shall be positioned below level A as shown in Figure 1. This exposure shall be timed for one minute after which each rod shall be thoroughly rinsed and dried.

Step 6. The rods shall be weighed to within  $\pm 0.001$  grams. The exposed area of each rod shall be determined to within 2 per cent of the true area. The weight loss is the difference between the original weight of Step 1 and this final weight. The weight lost per unit area for each rod shall be calculated by dividing the weight loss in milligrams by the exposed area in square inches to obtain  $\text{mg/in}^2$  (milligrams lost per square inch).

Step 7. The average weight loss per unit exposed area for the six rods shall be calculated. The calibration test shall be considered valid only if each individual weight loss is within 15 per cent of the average weight loss.

Calibration Results. The ultrasonic unit shall be considered correctly calibrated only if the average weight loss per unit area in a valid calibration test is  $100 \pm 15$  milligrams per square inch.

Calibration Adjustments. If the calibration is found to be incorrect, three types of adjustments or corrective action may be applied as follows:

- (A) The depth of the ultrasonic bath may be changed.
- (B) A different aqueous ultrasonic bath solution or some dampening shield may be employed.
- (C) The ultrasonic generator may be tuned to lower its

power output provided the frequency is  $40 \pm 3$  kilocycles.

Procedure. The ultrasonic bath shall be filled with the ultrasonic bath solution to the fixed level in accordance with step 2, calibration of ultrasonic unit. Four (4) test tubes containing  $10 \pm 0.5$  ml of the test solution shall be prepared and suspended into the ultrasonic bath in accordance with step 3, calibration of ultrasonic unit. The ultrasonic unit shall be turned on and all adjustments necessary to provide the correct calibration shall be made. The ultrasonic unit shall be on and correctly calibrated during all porosity tests (see calibration of ultrasonic unit). The contacts to be tested shall be selected in accordance with 4.3.4. One plated contact to be tested shall be positioned into each of the four (4) test solutions receiving the ultrasonic agitation as in Figure 1. The contacts shall be completely submerged in the test solution and also entirely below level A. The test part shall be subject to this exposure for  $4.0 \pm 0.1$  minutes. After the timed exposure, the contacts shall be removed immediately from the test solution.

Note: The test specimens should not touch the glass surfaces during the test period.

Measurements. Visual estimation of porosity by comparison shall be made not later than ten minutes after termination of the test. The volume of the unknown and the standard shall be identical; the test tube employed for comparison shall be identical. Comparison of color depth shall be done by looking through the test tube openings when the tubes are held against a white paper background. The lighting characteristics of the unknown and the standard shall be identical. The presence of more copper is indicated by a darker blue color.

Results. The copper content of each of the test solutions shall be estimated to within 20 per cent of the true content and shall be recorded. All of the test solutions shall be mixed and made homogeneous. The color density of the mixed solution shall be compared to that of the requirement standard (see Table V). If the color density of the mixture exceeds that of the requirement standard, the lot represented by the tested samples shall be rejected. If the color comparison is such that the color density appears identical to that of the requirement standard (see Table V) or is in doubt, the lot shall be rejected except when the copper content determined by a chemical analysis is less than the required content in Table III (see 3.4.5).



#### 4.5 Rejection

##### 4.5.1 Rejection by Visual Inspection, Nondestructive Tests.

Any item in the sample selected in accordance with 4.3.3 having one or more defects shall be considered defective. If the number of defective items exceeds the acceptance number of the appropriate sampling plan of Standard MIL-STD-105, the lot represented by the sample shall be rejected. Disposition of rejected lots shall be in accordance with MIL-STD-105.

4.5.2 Rejection by Destructive Thickness, Adhesion, or Hardness Tests. If any item in the sample, selected in accordance with 4.3.4, fails the requirement for either thickness, adhesion, or hardness, the lot shall be rejected. Lots of plated articles rejected by destructive thickness, adhesion, hardness or porosity tests may be reprocessed and resubmitted for testing under conditions specified by the procuring agency.

#### 5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be as specified by the detail specification covering the item on order (see 6.1). If there are no detailed specifications, preparation for delivery shall be as specified by the procuring agency.

#### 6. NOTES

##### 6.1 Data Required on the Detailed Specification:

- (1) Title, number and date of this specification and specifications covering any required underplatings.
- (2) Type, subtype and thickness class required. Minimum thickness greater than 0.000500 inch shall be specified.
- (3) All strikes and underplating required.
- (4) Special properties, tests and certifications.
- (5) Preparation for delivery required.

6.2 Supersession Data. Due to the changes in class designations, Table VI provides a cross reference between the thickness classes of this specification and that of MIL-G-45204.

TABLE VI

Plating Thickness In Inches	CLASS	
	MIL-G-45024	This Specification
*0.000050 max.	-	1
0.000050 min.	1	2
0.000100 min.	2	3
0.000150 min.	-	4
0.000200 min.	3	5
0.000300 min.	4	6
0.000500 min.	5	7
above 0.000500 min.	-	8
0.00150 min.	6	(Included in Class 8)

\*Sufficient thickness to provide complete gold coverage.

B. RHODIUM PLATING OF CONNECTOR CONTACTS, GENERAL SPECIFICATION FOR

1. SCOPE

1.1 This specification covers the deposited high reliability rhodium electroplating applied to pin and socket non R.F. electrical connector contacts. The contacts to which the rhodium is to be applied shall be machined of one of the following: leaded copper, nickel silver, nickel iron, phosphor bronze, chrome copper, beryllium copper, leaded brass or tellurium copper. The purpose of this specification is to assure the highest standards of quality for rhodium electrodeposits on electrical connector contacts in order that functional reliability needed for such contacts is maintained and assured.

1.2 Classification. Rhodium platings required to meet this specification shall be of the classes defined in Table I.

TABLE I  
Class Designations

Class	Minimum Thickness Inch
1	0.000030 min.
2	0.000050 min.
3	0.000100 min.
4	*(greater than 0.000100)

\*Shall be specified in the detailed specification.

2. APPLICABLE DOCUMENTS

2.1 The following standards, of the issue in effect on date of invitation for bids, form a part of this specification.

STANDARDS

Federal

Fed. Test Method Std. No. 151-Metals;  
Test Methods

## Military

MIL-STD-105-Sampling Procedures and Tables for Inspection by Attributes.

MIL-STD-109-Inspection Terms and Definitions.  
Air Force Project Nr. 7-960 Final Report

### 3. REQUIREMENTS

3.1 Plating Materials and Processes. The materials and processes used shall produce coatings that meet the requirements of this specification.

3.2 Basis Metal. The basis metal shall be free from all defects that will be detrimental to the utility, appearance or protective value of the plating.

#### 3.3 Process Requirements.

3.3.1 Preplating Operations. Unless otherwise specified in the detailed specification (see 6.2), rhodium plating shall be applied after all basis metal heat treatments and mechanical operations (such as machining, brazing, welding and forming) have been completed. If postplating operations are necessary, such operations shall be performed before acceptance tests.

3.3.2 Surface Cleaning and Activation. The surface shall be cleaned and activated by a process optional to the plater if it is not specified in the detailed specification. Care shall be taken in the use of bright dips or other etchants to prevent excessive metal loss where dimensional tolerances and surface characteristics must be maintained.

3.3.3 Strikes and Underplating. A strike electrodeposit of copper shall be applied to the basis metal if the basis metal is a copper based alloy. When the basis metal is nickel-iron, a nickel strike such as a "Woods Nickel" shall be applied to the basis metal. Unless otherwise specified, a silver or nickel underplate shall be applied prior to plating rhodium.

3.3.4 Plating. Activation shall immediately precede all plating operations. Unless specified in the detailed specification, the plating process and plating solutions employed shall be optional provided that the selected process produces platings which meet the requirements of this specification.

3.3.5 Rinsing. After plating, residual plating salts shall be removed from plated articles.

### 3.4 Properties of Plating.

3.4.1 Thickness. The rhodium thickness shall be measured in accordance with 4.4.2. The thickness requirement in Table I (see 1.2) shall be met for the class that is specified and shall apply to all functional and significant surfaces. Unless otherwise specified, metallic surfaces of the contacts to which the plating solution has access shall be covered with rhodium sufficient to exhibit a uniform rhodium color.

Functional Surfaces are those surfaces so defined by the detailed specification. These are areas that are usually subject to wear and corrosion.

Significant Surfaces are those surface areas that can be touched by a ball having a diameter of 0.75 inches unless they include the following interior surfaces. Interior surfaces such as holes, slots, keyways or similar configurations beyond a distance within the configuration and equal to the smallest dimension of the entrance are not significant surfaces.

3.4.2 Appearance. (see 4.4.1). The rhodium plating shall be free from nodules, blistering, tarnishing, peeling, flaking, pits, burned areas and discontinuities such as unplated areas, gouges, scratches and cracks. Any other visible defects which detrimentally affect the utility, protective value and wear resistance of the plated contact shall be cause for rejection. Rack marks shall not be acceptable unless specified on the detailed specification. The plating shall be uniformly smooth over all functional surfaces, (see 3.4.1). Basis metal defects which cause plating to be irregular and/or discontinuous shall be cause for rejection, (see 3.2).

3.4.3 Adhesion. The rhodium plating, including any electro-deposited underplating, shall adhere to the basis metal and/or to the underplating and shall show no separations when tested in accordance with the Baking Test 4.4.3.1. The Bend Test 4.4.3.2 and the Cutting Test 4.4.3.3 shall be performed when specified in the detailed specification.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Process Control. High quality electrodeposited coatings on connector contacts shall be maintained by adherence to superior processes as well as regular maintenance of solution compositions and calibrations of equipment and controls. Platers shall maintain complete records and practice these qualities of good workmanship.

4.2 Responsibility. Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements prior to the submission for government inspection and acceptance. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. Inspection records of the examinations and tests shall be kept complete and available to the government as specified in the contract or order.

4.3 Sampling Plan. Inspection and testing required herein shall consist of lot-by-lot inspection.

4.3.1 Lot-by-lot Inspection. Connector contacts selected for lot-by-lot inspection shall be sampled in accordance with 4.3.3 for nondestructive tests and in accordance with 4.3.4 for destructive tests.

4.3.2 Lot. A lot shall consist of contacts conforming to the same part number, plated by the same processes with the same equipment, and submitted for inspection at the same time.

4.3.2.1 Proof of Identical Production. When required by the procuring agency or the government inspector, the contractor shall furnish proof that all articles in a lot submitted for inspection were plated under as nearly identical conditions as possible. Such proof may include information on the racking of parts, composition of solutions, voltages, current densities, cycle time and temperatures during plating operations.

4.3.3 Sampling for Nondestructive Tests. Samples for non-destructive tests shall be selected in accordance with MIL-STD-105, inspection level III. Acceptable quality level (AQL) shall be 1.0 per cent defective. Other sampling procedures may be substituted when authorized by the procuring agency.

4.3.4 Sampling for Destructive Tests. Unless otherwise specified, the samples for destructive tests shall be

composed of four plated contacts selected at random from each lot. The procuring agency may change the number of samples required or specify the use of other sampling procedures.

#### 4.4 Acceptance Tests.

4.4.1 Visual Inspection for Acceptance. Samples selected in accordance with 4.3.3 shall be visually examined for compliance with the requirements of 3.4.2. The samples shall be examined at a minimum of four-power magnification. If the number of defective samples exceeds the permissible acceptance number for the size of lot under inspection, the lot represented by the samples shall be rejected.

4.4.2 Thickness of Plating. The plating thickness shall be measured by any suitable method capable of giving results which are within 5% of 0.000005 inch of the true thickness. Unless otherwise specified, thickness readings shall be taken from each of six (6) plated contacts sampled at random from the lot. A minimum of three (3) thickness readings shall be taken from each of the sampled contacts. If a functional surface is specified, the readings shall be at random locations on the functional surfaces, (see 3.4.1). If a functional surface is not specified, the thickness readings shall be at random locations on the significant surfaces, (see 3.4.1). If any thickness reading taken from a functional surface is less than the specified minimum, the lot represented by the samples shall be rejected, (see Table I). When the functional surface is not specified, the lot shall be rejected if the average of the thickness readings taken from any contact is less than the specified minimum, (see Table I).

Method 521 (microscopic method) of Fed. Test Method Std. No. 151 with the modification of Table II shall be used in cases of dispute.

TABLE II  
Modification in Procedure for Test Method 521  
(Fed. Test Method Std. No. 151)

Step In Test Method 521	Modification
Selection of Section for Test	Use a perpendicular cross section of the selected specimens.
Preparation of specimens; mount- ing specimens.	Plate the articles with a coating at least 0.003 inch thick of copper, nickel or iron to protect the edges during grinding and polishing. The first layer of overplate should be a copper strike deposited from a cyanide solution, fol- lowed by the relatively thick overplate.
Preparation of section.	Grind and polish as indicated, following the instructions for polishing zinc, cadmium, tin and lead coatings.
Etching.....	Use an etching solution consisting of one part nitric acid (specific gravity 1.42) to 19 parts alcohol (95 per cent).
Procedure; use of microscope.	Take a minimum of five measurements at random locations on the specimens. Mea- surements shall be expressed to five decimal places. The magnification should be at least 500 diameters.

#### 4.4.3 Adhesion of Plating.

4.4.3.1 Baking Test. Plated samples selected in accordance with 4.3.3 shall be heated for 1/2 hour at 375°F +/- 10°F. Evidence of flaking, peeling, cracking or blistering shall be cause for rejection of the test contacts. If more than 1.0 per cent of the sampled contacts have such defects, the lot represented by the sampled contacts shall be rejected. This test is nondestructive, and non-defective contacts tested by this method may be returned to the lot.

4.4.3.2 Bend Test. Plated samples for the Bend Test shall be selected in accordance with 4.3.4. The test samples shall be



repeatedly bent  $180^{\circ}$  in any direction around a diameter equal to the thickness of the specimen until the basis metal fractures. The plating adjacent to the fracture shall be probed with a sharp instrument in an attempt to detach such plating. Any plating detached from the basis metal in this manner shall be cause for rejection of the lot from which the contacts were sampled.

4.4.3.3 Cutting Test. Plated samples selected in accordance with 4.3.4 shall be cut away from the basis metal with a sharp edged tool and examined under four power magnification. Evidence of lack of adhesion shall be cause for rejection of the lot represented by the sampled contacts.

#### 4.5 Rejection.

4.5.1 Rejection by Visual Inspection, Nondestructive Tests. Any item in the sample selected in accordance with 4.3.3 having one or more defects shall be considered defective, and if the number of defective items exceeds the acceptance number of the appropriate sampling plan of Standard MIL-STD-105, the lot represented by the sample shall be rejected. Disposition of rejected lots shall be in accordance with MIL-STD-105.

4.5.2 Rejection by Destructive Thickness, Adhesion. If any item in the sample, selected in accordance with 4.3.4, fails the requirement for either thickness or adhesion, the lot shall be rejected. Individually plated articles or lots of plated articles rejected as defective may be reprocessed and resubmitted for testing under conditions specified by the procuring agency.

#### 5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be as specified by the detailed specification covering the item on order, (see 6.2). If there are no detailed specifications, preparation for delivery shall be as specified by the procuring agency.

#### 6. NOTES.

6.1 Intended Use. Rhodium plating of connector contacts is intended to provide corrosion resistance and resistance to galling of sliding electrical contacts in low and high temperature applications.

## 6.2 Data Required on the Detailed Specification.

- (1) Title, number and date of this specification and specifications covering any required underplatings.
- (2) Thickness class required. Minimum thickness greater than 0.000100 inch shall be specified.
- (3) All strikes and underplating required.
- (4) Special properties, tests and certifications.
- (5) Preparation for delivery required.

## 6.3 Miscellaneous notes.

6.3.1 Rhodium Metal in Concentrated Solution. It is difficult to prepare a suitable salt in a constant and uniform solution; this is best done during the manufacture of the salt under rigorous scientific control. The metal for plating purposes is sold in the form of a concentrated compound in solution and can be obtained from laboratory chemical manufacturers.

6.3.2 Safety Caution. In making up the plating bath, it is important that the acid be added to the water before adding the rhodium concentrate to prevent precipitation of rhodium compound by hydrolysis. Never add water to the concentrated acid, as explosive steaming may occur and throw acid from the container.

6.3.3 Handling. Plated parts shall be handled with clean gloves and wrapped in neutral tissue paper for temporary storage.

XXVI.

#### VALUE ENGINEERING

Within the layout of work for this entire development program, special consideration was given to value engineering. A value engineering program is defined as a continuing and intensive appraisal of all elements influencing the cost of Air Force material and the elimination of those factors which contribute to an item's costs but are not necessary for required functional performance and other aspects of quality assurance. The basic idea of a value engineering program is designed to study and evaluate any elements of an end item design (including material), manufacturing processes and tool design which offer the greatest potential for minimizing the cost of the item for initial prototype quantities, and reducing the cost of potential follow-on quantities.

It should be noted, however, that the afore written value engineering description is in contrast to the value engineering program herein conducted due to the specialized nature of this program. An adaptation in value engineering was necessary, due to the fact, that the above definition of value engineering was designed for manufacturing programs where a product was involved. This includes research and development programs that are directed toward development of new or improved products at a lower cost. Due to the fact that this program's only output is engineering information, it was necessary to take a slightly different approach to value engineering.

This approach was divided into two categories of which the first was the value engineering of all procurement procedures for all material, equipment, and services to be used within this contractual work. The second approach was to evaluate all technical developments, procedures and material from an economic or value engineering point of view. Therefore, in all cases where there was an opportunity to evaluate any aspect of the contractual work, this contractor evaluated all possibilities available to him with the ultimate goal of keeping costs at a minimum which do not effect the functional performance and other aspects of quality assurance. All procedures, sequences, and operations herein developed were designed to keep cost at a minimum without sacrificing the highest obtainable quality. The engineering effort applied to this end has been coincidental with the engineering of the technical aspects of the contract work.

XXVII.

SUMMARY (Conclusions)

A. Literature Search; User Survey and Pilot Plating Line

Due to the comprehensive nature of this program, it was necessary to have specific requirements and guide lines for this contract. These requirements include the evaluation and study of contacts within the temperature range of  $-55^{\circ}\text{C}$  to  $+250^{\circ}\text{C}$  and for frequencies below 20,000 cps. The guide lines set by the Air Force were broad in scope, yet defining in nature. It should be realized, relative to the broad scope, that an exhaustive investigation of any one area of plating would have encompassed a much larger program than this total contract. Therefore, the results here are generally directed toward upgrading the quality level of connector contacts and not directed toward new developments due to extensive investigation in any one area of plating. It, therefore, must be recognized that this was not a research contract, but a manufacturing methods contract. This meaning that the results from this work accentuates practical test standards and processes as opposed to scientific development work as such.

The literature search conducted in Phase I of this contract proved unrewarding. The lack of relevant literature was evident. Much literature was published on the topics that were considered in this investigation, however, most of these papers basically did not contribute to this effort, due to the specialized nature of this program. Papers were often related in topic but not in the specific subject that was being investigated. This was due to the individual application being considered with a paper. We were often misled during the literature search, because we sorted relevant literature by analysis of the title. This resulted in choosing appropriate literature with a title like, Plating for Low Level Electrical Contact Applications, and then found, due to the specialized nature of this program, that this article was not possibly cryogenic applications. There was found, however, sufficient material on plating solutions and plating techniques that is available from plating handbooks and suppliers technical material. Information was available on processes and quality assurance test standards for plating, however, this was often found to be incomplete and outdated.

It was from the user survey that we acquired most of our information and were able to actually lay the ground work for the specific direction of this program. This survey covered an area from

the west coast to the east coast and included twenty-four organizations surveyed.\* This included interviewing approximately fifty engineers and scientists during thirty conferences. The information came in many forms; from air frame manufacturers, connector vendors, connector users, a contact plating subcommittee, other government contracts and programs similar to this one, as well as from industrial and job shop platers. The user survey was conducted to study the connector industry that used, manufactured, or plated military connectors. The following briefly summarizes the topics covered in the survey.

We surveyed for information related to electrical connector contact plating, from which our objective was to establish the most feasible approach to quality electroplating on MIL-C-26636 electrical connector contacts. This included the entire sequence of operations necessary for the economical electroplating of silver, gold, rhodium, and other applicable contact plates in order to assure maximum quality of usable contacts for a given production lot.

The survey covered basic circuitry application trends for various types of low frequency (non RF types), and low temperature connectors with an ambient temperature range of  $-55^{\circ}\text{C}$  to  $+250^{\circ}\text{C}$ . Factors also surveyed were physical structures in various sizes of associated electroplated contacts, together with the currents and ranges of frequencies conducted through each size.

Throughout all of the conferences arranged and held by Nu-Line Industries, Inc. to determine use trends and field failure problems for electrical connectors, we found a great deal of emphasis placed on general connector problems. The prime focal point, and the topic of most interest within the users surveyed, was to achieve improved contact reliability and to increase standardization of manufacturing methods which would include process control. In conjunction with this, however, there was one major division in the thinking of those engineers surveyed. That division basically centered around the pros and cons in the use of silver as a contact plate. Engineers either wanted silver as a contact plate, due to lower cost, better electrical conductivity, or they were satisfied with the level of reliability they were getting; or they wanted gold, or gold over nickel, because of better reliability, better wear properties with the hard gold, no contamination problems due to sulfides, oxides, etc.; and because gold may be generally used in more environmental conditions than silver.

\*Reference: Users Survey; Section III; Page 24.

It should be noted that various other contact plating combinations were also discussed throughout this survey. However, these discussions primarily centered around gold, silver, nickel, and rhodium in various combinations thereof. These combinations particularly were rhodium over silver, gold over nickel, and silver over basis metal.

All the organizations contacted during this survey felt that the industry could be substantially benefited by additional and improved electroplating specifications. From a study of the composite opinions and reasons that had been offered, we concluded that this could be accomplished by strong emphasis on product test standards and process controls.

The conclusions made from the user survey are listed in the following section for purposes of efficiency and ease of evaluation.

1. All parties contacted felt that the industry could be substantially benefited by the preparation of quality assurance test standards. This includes the preparation of plating methods and processes to compliment all plating standards and quality assurance guides.
2. There was a good deal of misunderstanding and lack of knowledge about plating and plated products. This caused inaccuracies in identifying failures. In the past, the trend has been to criticize plating and incorrectly attribute component failures to plating deficiencies.
3. Currently the emphasis seemed to be placed on other causes of failure. Persons not appreciating the intricacies and properties of plating will not fully consider the metal finish when evaluating a connector problem.
4. Large manufacturing organizations have established capable metal finishing departments as a result of their previous needs.
5. Most organizations surveyed, felt that the connector vendor should supply the industry with personnel capable of training the users' employees in connector handling and assembling.

6. The contact plate combination considered by the industry as the basic and most reliable is 0.00003 inch to 0.00005 inch gold over any thickness of nickel up to 0.0002 inch.
7. Porosity test is necessary for all incoming plated contacts within a given organization.
8. Adequate assurance of plating thicknesses on electrical contacts should be provided by the plating vendor to a contact user.
9. Most users do not load a connector over 50% of its current rating.
10. Most existing MIL connector specifications are design specifications rather than performance specifications. They were basically written around proprietary designs.
11. There were many complaints on poor connector design and connector application.
12. The test methods and test procedures included in the connector specifications are not adequate. They do not fully tie down what the user is getting.
13. The industry does not spell out basis metals for contacts, but they do spell out the electrical and mechanical requirements of a contact.
14. Skin-effect was insignificant in contacts relevant to the connector contacts herein investigated.
15. The importance of clean, well organized plating facilities, with appropriate equipment and controls were often neglected and even overlooked when the plater did not recognize the importance and increased reliability manufactured into a product as a result of such a facility. This was particularly true for job shop platers.

It is important to note here that plating on contacts does not stand alone. Many connector engineers surveyed were not aware of the engineering influences there are on quality plating of electrical connector contacts. In particular we reference; basis metal finish, plating current density, the functions of

plating thickness and barrier platings, process controls, and in particular, the importance of the choice of the plating combination for a given contact. To exemplify a point, there were situations found whereby a connector user's choice of contact plating was based upon what the engineer before him, and the engineer before that, had used, and if it was good enough for them, it is good enough for me. It is important that the connector industry understands the importance of engineering before and after plating as well as the importance of the quality level, or caliber of a plating facility.

In direct contrast to the above situation was the fact that we did find organizations with very reputable contact plating facilities. These facilities were usually only found in large companies, which in each case they explained that they were forced into setting up their own plating facility due to previous needs. These needs being better and more reliable electroplating. However, within a plating department of a large organization, there are often outside influences affecting plating procedures and operational requirements that do detract from the efficient operation thereof. These influences usually reflect the thinking of management or design engineering. Plating engineers interviewed felt that this was a problem for them because processes and test standards were often manipulated to better suit a cost picture or a design function, disregarding plating problems or techniques. It was felt that when the control of plating processes left the hands of the plater, a lower level of quality resulted. These situations create special organizational and procedural problems which must be solved to maintain a competitive position. The relative significance of these problems depends upon the company's product, production volume, and the nature and origin of their reliability requirements. It is felt that this is especially true where military contracts are concerned. These large company connector platers were also concerned that when the direction of plating left the hands of the plater, that the influence of management as well as design and production engineers often resulted in decreased quality of plating. Poor feedback of information on field failure problems was not only a general complaint of these platers, but of most connector people. These platers felt that with improved reliability information, they could better evaluate and alleviate contact failures due to plating.

Relative to the level of plating standards and general application of contact plates in other companies surveyed, the following conditions existed.



1. It was found that there was considerable misinformation about plating and plated products. This has caused inaccuracies in identifying failures. We found that here the trend was often to criticize plating and to incorrectly attribute component failures to plating deficiencies.
2. We also found the paradox of the above situation where in some cases the emphasis seemed to be placed on other causes of failure. Persons not appreciating the intricacies and properties of plating will not fully consider the metal finish when evaluating a connector problem.

A summary discussion on the pilot plating line is not included here due to the fact that it is covered in Section IV, page 54, of this report and is not an engineering data section, but only a description and equipment listing of a facility.

B. Basis Metal Cleaning, Crimp Evaluation, Rinsing Practices, Electrical Conductivity, Thermal Conductivity, and Hardness Testing.

The objective of this work segment was to investigate the characteristics of the seven contact basis materials outlined earlier in this report.\* The purpose was to assure us that the basis metals used herein were similar to those used by the industry for the manufacture of contacts and that these materials had the same properties thereof. It also would give us a better understanding of the materials being used and some of the problems that might be involved.

Although during this work segment many separate studies were made, primary importance was placed on crimp evaluation, basis metal cleaning, and rinseability. The last two sections listed cannot be adequately summarized due to the nature of the material contained therein. It is important to note here that both of these subjects are considered by this contractor as of prime importance in the manufacture of high reliability pin and socket connector contacts. These two were reported in detail within this report for ease of comprehension, and as part of our effort to establish quality assurance guides for the electroplaters.\*\*

\*Reference: Section V , page 64.

\*\*Reference: Section IX, page 74, and Section X, page 104.

The referenced work on crimp evaluation was to investigate for the purpose of and to the extent that the plating standards, controls, and processes being established in the over-all contract work would be consistent with requirements for contacts of the crimp type.

The approach taken in investigating crimping was to test and evaluate the following characteristics:

1. A measure of the millivolt drop across the crimp for each material and hardness level investigated.
2. A tensile strength test of the crimp for each given material and hardness thereof.
3. A photomicrograph study of crimp cross sections.

The millivolt drop data revealed a definite pattern in the values before and after temperature durability. The percent change in millivolt drop (which is a measure of joint resistance change) is consistently higher for the softer metals.

The tensile strength data shows a trend of higher values of tensile for softer metals with an indication of an optimum level per metal. Beyond this optimum further reductions of hardness start to show lower values of tensile strength.

The cross sections also indicate a nominal hardness level for the best crimp conditions. It must be understood that with these changes in hardness there can be significant changes in ductility which will simultaneously effect the crimp quality.

The hardest materials such as beryllium copper and phosphor bronze #1 excessively deformed the wire strands reducing the wire cross sectional area. These crimps show poor tensile strength.

In the case of the full hard leaded brass, there was not sufficient ductility to withstand the crimping action and fracture occurred in a high percentage of the parts. There was a slight tendency for fracture in the half hard brass also.

Quarter hard brass had sufficient ductility to respond well to the crimp action and formed well to fill the entire cavity.

Leaded copper is at a suitable level in the full hard condition as received. The joint formed and compacted well. Half hard and quarter hard leaded copper produced joints exhibiting voids

and a lack of compression of the wire strand resulting from too much yield in the barrel.

Some contacts showed gaps between the crimp barrel wall and the wire indicating a springback of the wall after crimping. This results from an elastic rather than a plastic deformation of the crimp barrel.

The following is a list of the crimp ratings of the six basis materials as compared to the procured contact per MIL-C-26636, (procured contact rated 20).

MATERIAL	RATING	MATERIAL	RATING
Leaded Copper #1	17	Phosphor Bronze #1	4
Leaded Copper #2	11	Phosphor Bronze #2	8
Leaded Copper #3	9	Phosphor Bronze #3	16
		Phosphor Bronze #4	19
Chrome Copper #1	14		
Chrome Copper #2	16	Nickel Silver #1	4
Chrome Copper #3	14	Nickel Silver #2	11
		Nickel Silver #3	15
Beryllium Copper #1	4	Nickel Silver #4	11
Leaded Brass #1	0		
Leaded Brass #2	15		
Leaded Brass #3	19		

This summary section will cover the largest portion of the contract work, and, in particular, the work segments covering plating tests. It was during these segments that data was collected to develop optimum plating procedures for the electroplating of gold, silver, rhodium and other relative contact platings. Hundreds of plating tests were completed and resulting test data was compiled and compared on various charts, graphs and forms for the purpose of ease in comparing all possible parameters and characteristics of the work.

As a result of this, the following conclusions were made from those tests:

1. In all types of plating, it was found that as the thickness of plate increased, the porosity decreased.
2. All gold over nickel plating combinations having a total thickness of 0.000250 inch or more were found

to have no porosity per the Nu-Line Porosity Test method. In many cases 0.000150 inch was sufficient.

3. Pure Gold (soft gold) was found to be more porous and less corrosion resistant for equal thicknesses of plate than were hard gold platings.
4. The use of low plating bath parameters as discussed within this report, in almost all cases, gave greater porosity and less corrosion resistance than do platings obtained using standard levels.
5. Platings obtained using high bath parameters, and, in particular, bath concentration and current density at a minimum increase of twenty per cent, gave slightly less porosity and better corrosion resistance than those platings completed at standard parameter levels. When current density or bath concentration was increased individually, this was not as effective as it was when they both were increased together and plated.
6. High anode area did not seem to greatly effect porosity of any of the baths tested. However, low anode area (a decrease of fifty per cent or more) greatly decreased throwing power and increased porosity.
7. An increase, to a limit, of bath temperature in all cases increased throwing power, however, beyond a limit of usually twenty per cent, (this varies from bath to bath), the throwing power will tend to fall off again, and the color of the plate will change. In the case of pure gold (soft gold)plating the color would become quite orange and nodular.
8. The basis metal cleaning and activation procedures were found to be the one singular most important parameter that effected the quality of the plated layer and porosity. Applicable cleaning procedures will improve the microfinish of the basis metal which results in less porosity in the plated layer. Good cleaning procedures will also result in better adhesion, less effects of bleeding and, of course, a more efficient operation.
9. Agitation as such was not tested and evaluated as a function of each bath. However, it should be noted that with increased agitation, one will attain better throwing power, better leveling properties, less porosity and better color of plate from some baths.

10. A weekly, scheduled chemical analysis (or more often if required) was found to be an absolute necessity to maintain a reliable quality level of plating. The purpose here is to maintain a before the fact control on the quality assurance of plating thereby preventing the costly down time and the problems of having bad parts and the shut down of a plating station until you find your problem and correct it. Other tests that could be considered before the fact and that should be run on a periodic basis includes the calibration of all meters and regulating devices, the constant inspection and upkeep of equipment and most of all, complete up-to-date sets of test standards, process controls and procedures. This should be complemented by properly trained personnel who understand the intricacies and basic technology of plating and who are conscientious at their work.
11. Proper rinsing was proven to be necessary to attain good adhering plating. Extra caution should be made to rinse cleaning solutions thoroughly off a part before entering another cleaning bath or a plating bath. This is particularly true when you have small diameter blind holes which have the tendency to trap and drag solutions from one bath to another.
12. Always enter a plating bath at a minimum voltage equal to fifty per cent of that voltage level you will use. Then adjust the voltage immediately after entering the bath to the level you desire.
13. It is recommended by this contractor that all baths discussed herein be operated with constant filtration.
14. Skin effect does not exist in contacts applicable to the scope of this contract. That includes the MIL-C-26500 connector and the MIL-C-26636 contact which is designed for 20,000 cps. or less.
15. The survey letter basically proved unrewarding; however, it is included herein for purposes of showing work completed and for Air Force information.
16. The porosity test discussed and used during this contract was found most effective for this contract work as a relative quality assurance test for plating. However, this test would require modification and

improvement to be appropriate to the military and the industry.

17. The microfinish data did not help us a great deal in evaluating the reliability of a plated layer. However, it was important in the fact that we had a constant check to assure ourselves that we were staying within one of the requirements of the contract, that being a 10 micro on all basis metal before plating.
18. Visual inspection was valuable during this work and is always necessary by industry as a final test. We found numerous cases where the color or appearance of the plating was extremely poor, yet it passed all other tests at what would be considered a quality level.

#### Silver Plating

19. Silver plating gave consistantly lower porosity ratings or in fact, had more porosity than did any of the gold plated layers at equivalent thicknesses. The difference in porosity was great and considered sufficient by this contractor to recommend that it not be applied to any pin and socket high reliability non R.F. connector contacts.
20. The use of high plating parameter levels during plating tests made little or no difference in the porosity of the plating.

#### Orosene 999 Gold Plating

21. Orosene 999 gold plated at standard parameter levels and plated directly on basis metal with a copper flash will give a porosity of about 5.0 at a thickness of 0.00005 inch and a porosity of 7.5 at a thickness of 0.0001 inch. It requires 0.000135 inch thickness of Orosene 999 Gold to get a porosity rating of 10 per the test method used herein and when plated directly on basis metal.
22. Orosene 999 gold plated at both ten per cent and twenty per cent high bath concentration and directly onto basis metal including a copper flash gave slightly better results. A porosity of 5.5 was attained for thicknesses of 0.00005 inch and a porosity of 8.5 was attained for 0.0001 inch thickness of Orosene 999 gold plating. A porosity of 10 was obtained with the average thickness of 0.00011 inch Orosene 999 gold over basis metal.

23. Orosene 999 gold plated using twenty per cent high current density gave basically the same porosity as those tests plated at standard parameter levels.
24. Orosene 999 gold plated using twenty per cent high bath concentration coupled with twenty per cent high current density gave equal results as listed in number 22 for high bath concentration alone. That is to say that 0.00011 inch thickness of gold is required when plated under the stated conditions to obtain a porosity of 10.
25. Orosene 999 gold over silver plating had similar characteristics to other tests of gold over silver. In these tests, it required 0.000145 inch Orosene 999 gold to obtain a porosity of 10. Actually, in this case, the porosity appeared to get worse than when using gold alone. At this point, this characteristic cannot be accounted for.

#### HG Gold Over Basis Metal

26. HG Gold plated at standard parameter levels appeared to result in platings of slightly more porosity than did other hard golds using cobalt or nickel as their brightner. HG Gold contains a relatively high per cent of silver as a brightner as compared to the brightner content of most other hard gold baths. At standard parameter levels, HG Gold had a porosity rating of one at a thickness of 0.00005 inch and a porosity of 10 at a thickness of 0.000125 inch.
27. HG Gold plating tested at ten per cent and twenty per cent high bath concentration had much less porosity than did those tests conducted at standard levels. A porosity of 3.5 resulted for a thickness of 0.00005 inch; a porosity of 8 resulted for a thickness of 0.0001 inch and a porosity of 10 resulted from a thickness of 0.000110 inch.
28. HG Gold plating tested at twenty per cent high bath concentration and twenty per cent high current density gave slightly worse results or more porosity than did the tests at high bath concentration alone. For those tests using high current density and high bath concentration, it required a thickness of 0.000163 inch to obtain no porosity or a rating of 10.

29. HG Gold over silver also gave low porosity ratings, or in other words, they had much more porosity. The thickness of silver seemed to have little effect on the porosity rating. For a thickness of 0.00005 inch HG Gold over any thickness of silver, the average porosity rating was 1. For a thickness of 0.0001 inch HG Gold over any thickness of silver, the average porosity rating was 5. The thickness of HG Gold over silver required to obtain a porosity rating of 10 was 0.000160 inch.

#### Autronex CI Gold Plating over Basis Metal

30. Autronex CI Gold plated at standard parameter levels over basis metal with an appropriate copper strike gave the least porosity or some of the better porosity ratings in this contract work. At standard parameter levels 0.00005 inch Autronex CI Gold gave a porosity rating of 3 and at a thickness of 0.0001 inch gold gave a porosity rating of 10.
31. A marked decrease in porosity was shown with the use of high current density and high bath concentration at the thickness of plate of 0.00005 inch. There was no decrease in porosity with the use of twenty per cent high current density and bath concentration at a thickness of 0.0001 inch.
32. The porosity level of Autronex CI Gold was the same when comparing equal thicknesses of plate and the use of high current density as opposed to plating at standard parameter levels. This was true at thicknesses of 0.00005 inch to 0.0001 inch.
33. When high bath concentration alone was the only parameter change less porosity was obtained for platings in the 0.00005 inch thickness range as opposed to platings obtained at standard parameter levels.
34. No tests were conducted with Autronex CI Gold over silver plating.

#### Autronex N Gold Plating over Basis Metal

35. Porosity results from Autronex N. Gold plating were also relatively very good. Porosity rating for Autronex N Gold per the Nu-Line method and at standard



parameter levels was an average of 7 for a thickness of 0.00005 inch. It required an average of 0.00011 inch thickness of Autronex N to give a porosity rating of 10 (no porosity).

36. The use of high current density in this bath made no appreciable change in the porosity level of the plating.
37. No tests were done with this bath relative to high bath concentration.
38. Plating combinations with Autronex N over silver gave similar results as other gold platings over silver, that is, less corrosion resistance due to greater porosity. Thickness of silver plating had no effect on the porosity level of the plating combination. Porosity ratings of an average of 3 for thicknesses of 0.00005 inch and ratings of 10 were obtained for thicknesses of 0.00011 inch Autronex N Gold over silver.

#### Autronex C Gold over Basis Metal

39. Autronex C Gold gave the lowest average porosity of all the golds tested herein. The difference in porosity level between Autronex C and Autronex N, Autronex CI and Orosene 999 was only slight.
40. The average porosity rating for Autronex C plated at standard parameter levels on basis metal at a thickness of 0.00005 inch was 7. A porosity rating of 10 was obtained at an average thickness of 0.000095 inch.
41. Autronex C, plated using twenty per cent high bath concentration, and when plated with high bath concentration and high current density together, resulted with the same porosity rating as did tests at the standard levels. This was true for all thicknesses.
42. Autronex C plated at high current density resulted with platings of greater porosity than did Autronex C platings at standard levels.
43. No plating tests were conducted with Autronex C gold over silver plating.

#### Bright Gold Plating over Basis Metal

44. Bright gold platings resulted with greater porosity than did Autronex N, C, CI or Orosene 999 gold platings. Bright gold plated at standard parameter levels gave an average porosity rating of 5 at a thickness of 0.00005 inch. At a thickness of 0.0001 inch bright gold resulted in a porosity rating of 8. To attain an average porosity of 10, we had to go to a thickness of 0.00014 inch.
45. Tests applying high bath concentration together with high current density gave poorer results or greater porosity than did tests at the standard parameter levels.
46. Tests applying high bath concentration alone gave slightly better results or less porosity than did bright gold platings at the standard parameter level.
47. Tests applying high current density alone also gave slightly better results or less porosity than did platings at the standard parameter levels. This was particularly true at the thickness of 0.0001 inch.
48. No tests were conducted with bright gold over silver plating.

#### Temprex S Gold (Pure Gold-Soft Gold) over Basis Metal

49. Temprex S Gold plated at standard parameter levels and at a thickness of 0.00005 inch gave an average porosity rating of 5. At a thickness of 0.0001 inch, the average porosity rating was 7.5. To attain a porosity rating of 10 or no porosity per the Nu-Line Test Method, a thickness of 0.00015 inch was required.
50. Tests conducted using high current density and high bath concentration separately or together gave the same results as Temprex S plating tests conducted at the standard parameter levels.
51. No Temprex S Gold plating tests were conducted over silver plating.

Orotemp Gold (Pure Gold-Soft Gold) Plating over Basis Metal

52. Orotemp Gold plating gave low porosity test ratings. Porosity was severe at all thicknesses of plate and at any parameter variation tested. Plating tests were conducted from 0.000035 inch thickness to 0.0002 inch thickness.
53. Orotemp Gold plating tests were conducted over silver plating, and in all cases, the amount of porosity was high. Average porosity of 0.00015 inch thickness of Orotemp Gold over silver plating average thickness of 0.000125 inch gave a porosity rating of 6.
54. Average porosity rating of Orotemp Gold over basis metal at a thickness of 0.00005 inch was 3 and at a thickness of 0.0001 inch was 4.

All Gold Plating Tests Conducted over a Nickel Barrier Layer

55. Autronex C Gold plating gave a porosity rating of 10 when plated at standard parameter levels at a thickness average of 0.00005 inch and over nickel. The average thickness of the nickel in these tests was 0.000064 inch. Tests of greater thicknesses of either the Autronex C or the nickel in all cases gave a porosity rating of 10.
56. Autronex CI Gold at a thickness of 0.00005 inch over nickel plating gave an average porosity rating of 8 when plated at standard parameter levels. The average thickness of nickel in these tests was 0.00006 inch. An increase of 0.00005 inch thickness of plating for either the Autronex CI Gold or the nickel would give a porosity rating of 10.
57. Autronex N Gold at a thickness of 0.00005 inch over an average thickness of nickel of 0.0001 inch gave in all tests a porosity rating of 10. These tests were conducted at standard parameter levels.
58. Orosene 999 Gold at a thickness of 0.0005 inch over an average thickness of nickel of 0.00009 inch gave in all tests a porosity rating of 10. These tests were all conducted at standard parameter levels.
59. HG Gold plating at a thickness of 0.00005 inch over an average thickness of 0.00004 inch nickel gave a poro-

sity rating of 8. HG Gold plating tests with slightly thicker gold and nickel gave a porosity of 10.

60. Bright gold plating at a thickness of 0.00005 inch over an average thickness of 0.000057 inch nickel gave an average porosity rating of 7.2. A total thickness combination of 0.00015 inch nickel and gold plating would attain a porosity rating of 10.
61. Temprex S (Pure Gold-Soft Gold) plating at a thickness of 0.00005 inch gold over 0.000054 inch thickness of nickel gave a porosity rating of 7.
62. Orotemp (Pure Gold-Soft Gold) plating at a thickness of 0.00005 inch gold over 0.000058 inch thickness nickel gave an average porosity rating of 4. Orotemp platings with a porosity rating of 10 were attained when the total thickness of nickel and gold plate was a minimum of 0.0002 inch.
63. The porosity tests on nickel plating over basis metal showed that it required a minimum thickness of 0.0002 inch to attain a porosity rating of 10 or no porosity per the Nu-Line Test Method. Porosity tests conducted at less thicknesses gave random porosity ratings from 3.5 to 7. This would cover a range of thicknesses from 0.0001 inch to 0.00015 inch.

As part of the summary here, special attention should be paid to Section XXVIII titled "Recommendations." This is because we feel this is an intricate part of the accomplishments of this program. First, to establish abundant data on the parameters of the plating and cleaning processes, and then to recognize the limitations of the present work and the requirements of future work. This was accomplished by this program including the joint discussion of problems and the exchange of technical information by the Armed Services and commercial companies doing work in this area. The end result being a substantial contribution to the industry which, with the writing of this report, has not been fully analyzed or evaluated as yet.

XXVIII.

#### RECOMMENDATIONS

Nu-Line Industries, Inc. feels that the primary achievement of this contract, although the contract was not given for this purpose, was to educate some connector and plating people relative to the requirements for upgrading plating processes, quality assurance test standards, plating methods and guides. We feel that this contract has contributed in a twofold capacity: First, the fulfilling of the requirements outlined in the contract such as optimum plating procedures, basis metal cleaning procedures, etc., and second, the establishment of a foundation or a kickoff point to continue work in this field. It should be recognized that in this area, Nu-Line Industries, Inc. has only slightly scratched the surface, and the need to continue this work is a first rate requirement for either or both industry and the military.

The final conclusions and achievements listed in the summary of this report are only useful to a point. Beyond that point, further work must be done. If you have carefully reviewed the total work outlined in this report, and you truly have an understanding of the problems and objective, then you should first recognize the merits of the work to this point. But you should also recognize that alone this work has very limited value without continuation.

This contractor feels that it is our responsibility, having completed this work, that we should outline some of these areas that require further work. Note that these areas require further development work due to a growing gap between the quality and technological level of plating and the products on which it is applied.

#### A. Upgrade Existing Government and Military Plating Specifications

Discussion: In this contract report is included a rough draft of a suggested Air Force gold plating specification. It should be recognized that Nu-Line Industries, Inc. prepared this draft on the basis of work completed on this contract and also on the basis of present day levels of quality assurance for electroplating. This contractor does not intend to imply that this specification should replace any present day gold plating specification due to the fact that there has not been enough work and thus enough progress in

this area to make it worthwhile. In other words, although there is considerable improvement in this specification, it still is not adequate to do the job required by the military and the industry.

Before a final plating specification should be written, there should first be extensive work done in the area of quality assurance test standards for plating. This would include updating or replacing tests like the Salt Spray Test; the Bend Test; the Cutting Test; the Bake Test, etc. with more quantitative and reproducible tests. This should be followed by further development of manufacturing methods and process controls for electroplating. Finally, these methods and process controls should be complemented by a comprehensive outline of the characteristics and properties of all types of electroplating in a plating handbook.

This handbook should be so designed that buyers, design engineers and electroplaters can use it as a guide. However, it is important to point out that the scope of thinking by this contractor relative to the comprehensive information or characteristics and properties of electroplating is very broad. In other words, tests would be made to determine electrical characteristics under all types and degrees of weather and temperature, as well as to include tests on ductility characteristics, porosity, solderability, wearability, throwing power and many others, each as a function of each other, and in particular, temperature, type of plating, wearability, insertion withdrawal forces and contact resistances. Therefore, to accomplish the work suggested, that is, plating specifications complemented by a handbook, there requires a great amount of work.

- B. Prepare a Porosity Test Method Applicable to the Military; Industry, and all Types and Classes of Electroplating.

Discussion: The porosity test technique developed at Nu-Line Industries, Inc. and reported herein was adequate as a test for relative evaluations of one process against another or one plating against another. However, this test as it stands is not complete or diversified enough at this point to be appropriate or practical for industry. However, it is felt that this test with further modifications could be made into a practical and quantitative test method that would be efficient and easy to comprehend. It is felt that with further work, this test could be made applicable to all the requirements of the military and industry.

C. Upgrade Quality Test Standards for Electroplating.

Discussion: Primarily this was covered under (A) of this report section. However, this includes the updating and/or replacing the present test standards such as the Salt Spray Test; the Bend Test; Cutting Test; Bake Test, etc. that are presently being used by industry with more quantitative and reproducible quality assurance tests. To further emphasize the need of this requirement, the following quote is included here from MIL-STD-202C method 101B that covers the Salt Spray Test.

"Experience has since shown that there is seldom a direct relationship between resistance to salt spray corrosion and resistance to corrosion in other media, even in so-called "marine" atmospheres and ocean water. However, some idea of the relative service life and behavior of different samples of the same (or closely related) metals or of protective coating-basis metal combinations in marine and exposed seacoast locations can be gained by means of the Salt Spray Test provided accumulated data from correlated field service tests and laboratory Salt Spray Tests show that such a relationship does exist, as in the case of aluminum alloys. (Such correlation tests are also necessary to show the degree of acceleration, if any, produced by the laboratory test.). The Salt Spray Test is generally considered unreliable for comparing the general corrosion resistance of different kinds of metals or coating-metal combinations, or for predicting their comparative service life. The Salt Spray Test has received its widest acceptance as a test for evaluating the uniformity (specifically, thickness and degree of porosity) or protective coatings, metallic and nonmetallic and has served this purpose with varying amounts of success. In this connection, the test is useful for evaluating different lots of the same product, once some standard level of performance has been established. The Salt Spray Test is especially helpful as a screening test for revealing particularly inferior coatings. When used to check the porosity of metallic coatings, the test is more dependable when applied to coatings which are cathodic rather than anodic toward the basis metal. This test can also be used to detect the presence of free iron contaminating the surface of another metal by inspection of the corrosion products. The test is essentially the same as the Salt Spray (fog) Test described in Federal Standard 151a, Metals, Test Methods."

#### D. Mechanical and Electrical Tests for the Connector Contact.

Since the contact is basically the heart of a connector, continuing research must find better contact materials and plating finishes.

The choice of materials for both pin and sockets is a compromise between maximum strength, good producibility characteristics, conductivity and temperature properties.

For reliable connector performance contact plating must be durable, corrosion resistant, conductive and tenacious. To determine the best performance and relative merits of a contact, the following tests should be conducted:

##### 1. Mechanical

- . Contact engaging and separating forces.
- . Resistance to probe damage.
- . Durability Life Test.
- . Crimp Deformation.
- . Pin contact strength.
- . Tensile strength of crimp joint.
- . Corrosion resistance.

##### 2. Electrical

- . Current - temperature durability.
- . Contact resistance at temperature.

Upon reading the above, you may conclude that much work has been done in these areas. This is true if you are thinking in terms of contact basis materials. However, this work has not been done as a function of plating, for example, contact engaging and separating forces. With everything else being the same, a test comparing one plating to another will result in a wide range of engaging and separating forces. If temperature, the time pressure or the number of times were all varied and tested as part of an engaging and separating test program, and all as a function of plating, the resultant data would be useful to design engineers, buyers, production engineers, manufacturers and users. The same thing would be true for current, temperature, durability, contact resistance and many others.

An example of a design problem that could be solved from the suggested work is as follows. Imagine a contact application



that had to meet high durability requirements, a corrosive atmosphere and was used for dry circuitry applications. If the design engineer uses a hard gold to withstand the durability requirements, then he will probably not get the burnishing action that he would similarly get with soft gold which is required to break through a thin, nonconductive mono molecular layer. If, in turn, he uses a soft gold, he cannot withstand the durability requirements. The point being that with the completion of the work proposed, including comprehensive charts, graphs and tables, a design engineer can review the available information and locate the most reliable type and class of gold plating to meet his requirements. This plating may not be the complete solution to the problem, but it would be the best available. This same opportunity is, of course, available to the buyer who always calls out 0.00015 inch thickness gold plating for a particular application when actually according to a porosity or wearability table, 0.00012 inch thickness gold is sufficient. Information like this could save the military and industry large amounts of money not only in the saving of gold cost but also in getting the proper application of plating on a unit. Proper application of plating on a product could save reject costs, down time costs and product costs relating to replacement of a complete unit due to plating failure, etc.

E. Applicable Tests Correlating Physical and Electrical Properties with Plating.

Discussion: This includes the development of test data on insert-withdrawal forces and electrical contact resistance as a function of each other and as a function at various levels of temperature, plating combinations, current loads, time pressure, number of times, microfinish, etc. This program would be large in scope; however, it would result in more reliable connectors, connector contacts and higher, more reliable plating technology.

F. Military Plating Handbook

Discussion: This handbook would incorporate all the information developed herein on plating as well as including supplement section on parameters of plating not covered in this contract. This handbook would be complete in every way and would cover all aspects of plating. This handbook would go beyond any other material on plating to include not only more complete and updated processes and quality assurance tests but to include physical, electrical, durability,

temperature, etc. information organized in a comprehensive and clear fashion to help the buyer of plating, the design engineer applying plating to product and finally to the plater. It is intended that this would be the most complete book on electroplating technology available today.

G. Modify Present Contract Work to Adequately Apply to Various Reliability Levels of Plating.

Discussion: Although effort has been applied herein, on various levels of reliability relative to corrosion resistance of plating, further effort should be made to definitely tie down quantitatively these levels. Although the quality level of these plating combinations may be something less than the optimum attainable, if a quality level was established against a standard, the military and the industry may replace applications of gold with applications of tin-nickel, low purity gold plating or some other plating combination. This information could save endless dollars by any organization if applied.

H. Determine Temperature Application Ranges for Various Plating Combinations.

Discussion: This subject has been partially covered in earlier paragraphs of this report section. However, it is suggested that as part of this suggested work program, one of the objectives should be to attempt to find a replacement for the military and industry as well as the possibility that there may be available a plating that would meet the 250°C requirement of the MIL-C-26500 connector.

I. Determine Optimum Plating for R.F. Connectors.

Discussion: This requirement includes a complete engineering program designed to apply all the data obtained on the characteristics of electroplating as applied to non R.F. connectors, to then be applied to R.F. connectors and connector contacts. Also, this includes the determination of whether silver plating is completely functional as a contact plating for R.F. contacts or if and what plating might be more appropriate.